

Applied Remote Sensing for Mapping and Monitoring of the Great Lakes

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Laurentian Great Lakes



Laurentian Great Lakes

- Hold ~20% of Earth's fresh surface water.
- Over 30 million people live within the Great Lakes basin.
- Regular and accurate monitoring is necessary to protect the health of people and the environment.
- *In situ* measurements time consuming and costly, especially over large areas.



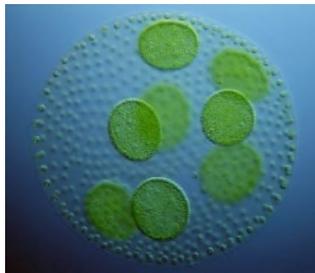
Remote Sensing for Great Lakes Mapping and Monitoring

- **Remote sensing:** The science of obtaining information about an object using a device that is not in contact with that object.
- Satellite-borne sensors provide a means to rapidly and repeatedly assess phenomena.
- Two basic categories of sensors:
 - Passive Sensors
 - *Electro-Optical (EO)*
 - Active Sensors
 - *Synthetic Aperture Radar (SAR)*
 - *Light Detection And Ranging (LiDAR)*

- Water Quality Products
- Harmful Algal Blooms (HABs)
- Submerged Aquatic Vegetation (SAV)
- Coastal Wetland Mapping
- Phragmites Adaptive Management

Water Quality Products

- Water color in inland and coastal water results mainly from three different parameters, known as Color-Producing Agents (CPAs):
 - Chlorophyll (CHL): A green pigment found in plant cells. Algal cells that are suspended in water produce a green-yellow color.
 - Dissolved Organic Carbon (DOC): Organic carbons that are produced as part of micro-organism metabolism or are transported from decaying vegetation products via rivers and streams. DOC only absorbs light, it doesn't scatter it. It appears yellow to brown in color (CDOM).
 - Suspended Minerals (SM): Inorganic particulate matter. Scatters and absorbs light.



CHL



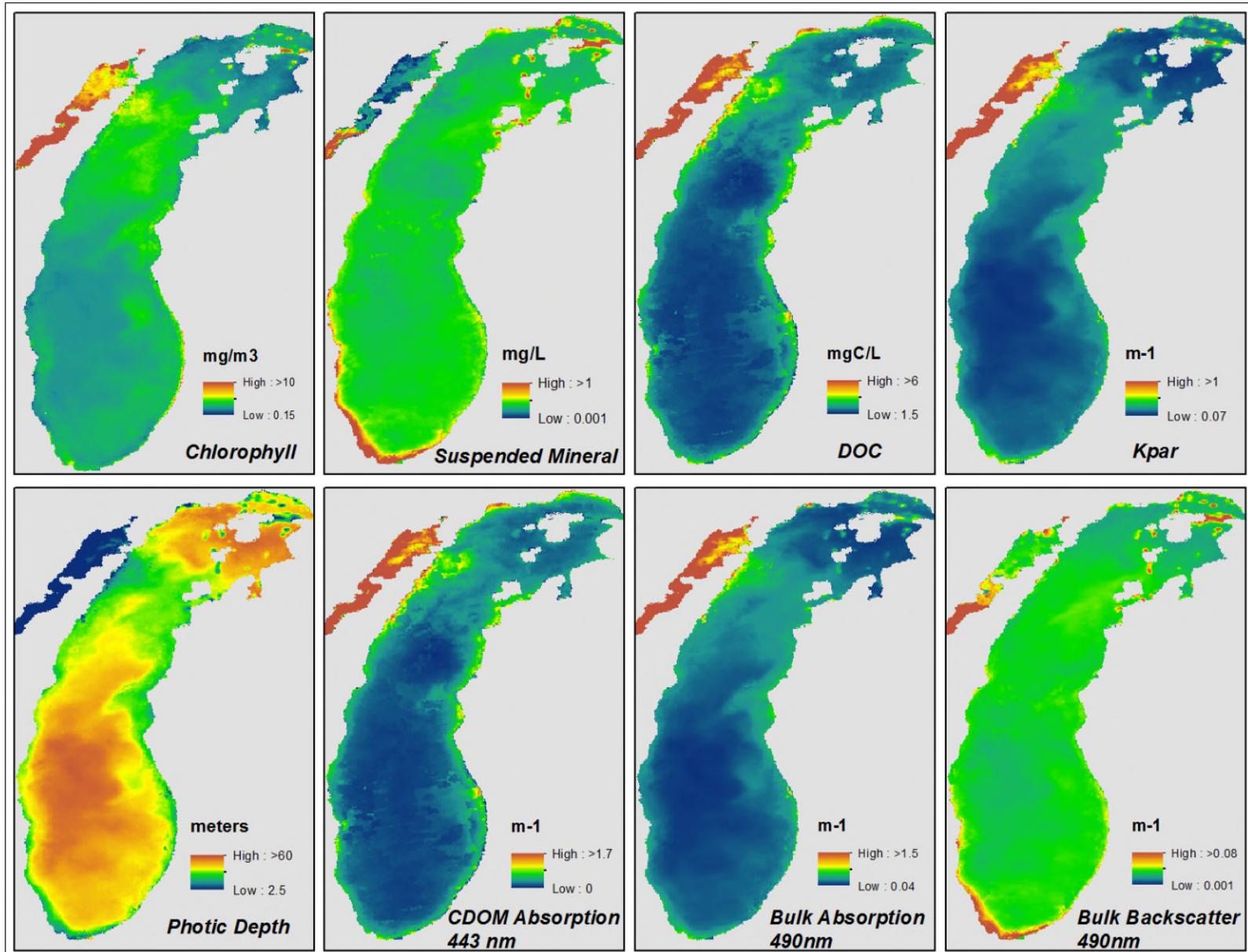
DOC



SM

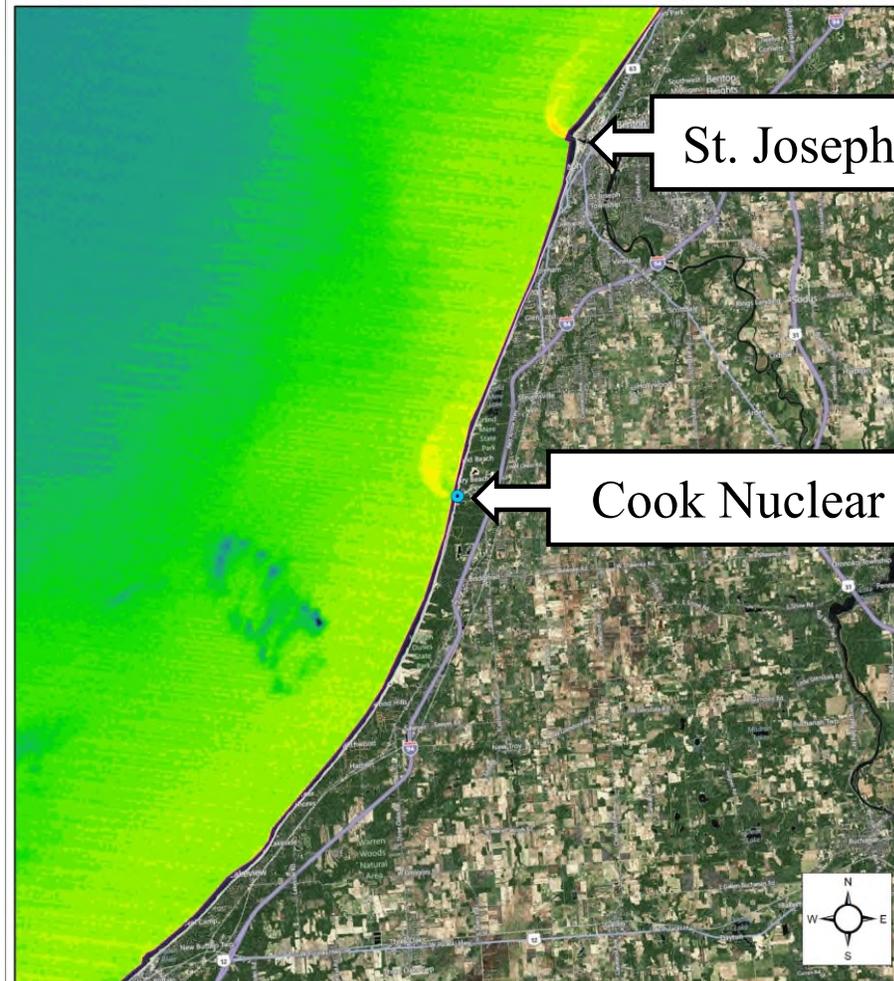
Water Quality Products

July 2013 Monthly Average Products for Lake Michigan



Lake Surface Temperature Products

Lake Michigan Surface Temperature near Benton Harbor, MI



St. Joseph River

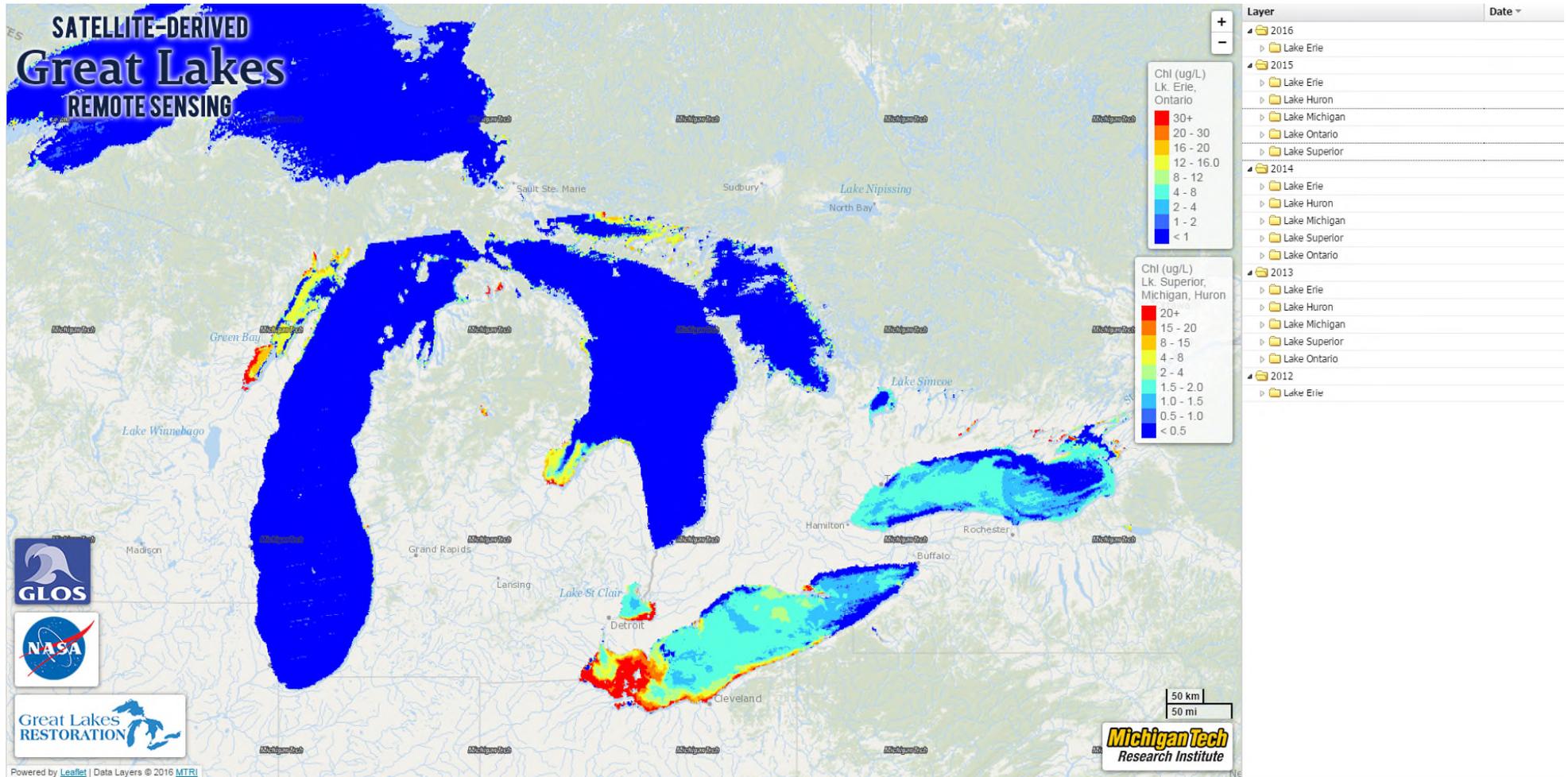
Cook Nuclear Plant

Sensor: Landsat 5 Band 6, Atmospherically Corrected. Date: June 04, 2011

Degrees Celsius	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	24 - 25	25 - 26	26 - 27	27 - 28	28 - 29	29 - 30		
No Data	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14	14 - 15	15 - 16	16 - 17	17 - 18	18 - 19	19 - 20	20 - 21	21 - 22	22 - 23	23 - 24	24 - 25	25 - 26	26 - 27	27 - 28	28 - 29	29 - 30

Map Scale 1:200,000
0 4 8 Miles
0 4 8 Kilometers

Path: J:\project\Limnotech_Thermal_Plumes\WXD\LimnoTech 2011 Lake Michigan Surface Temperature.mxd



<http://greatlakesremotesensing.org/>

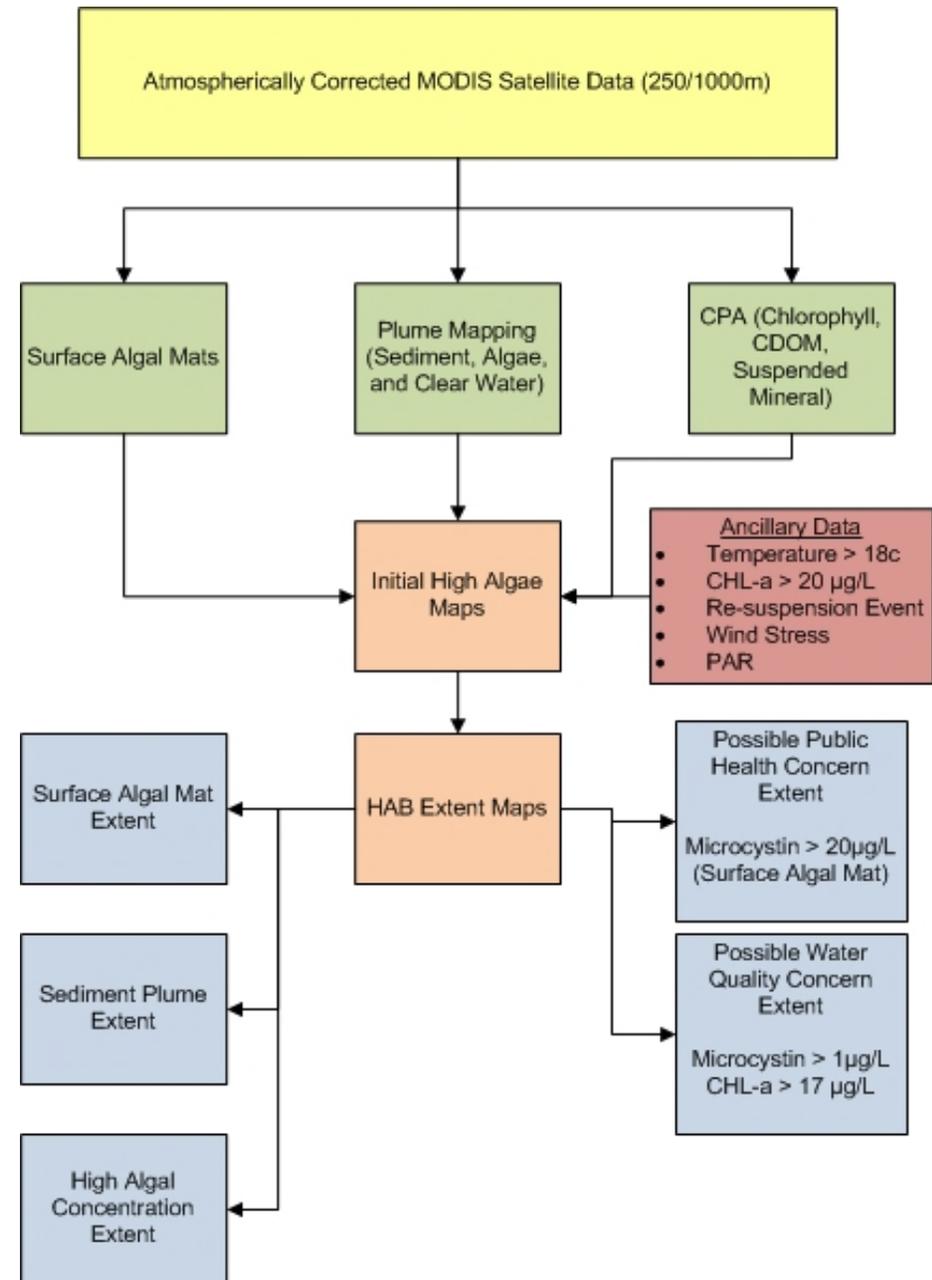


Harmful Algal Bloom Mapping

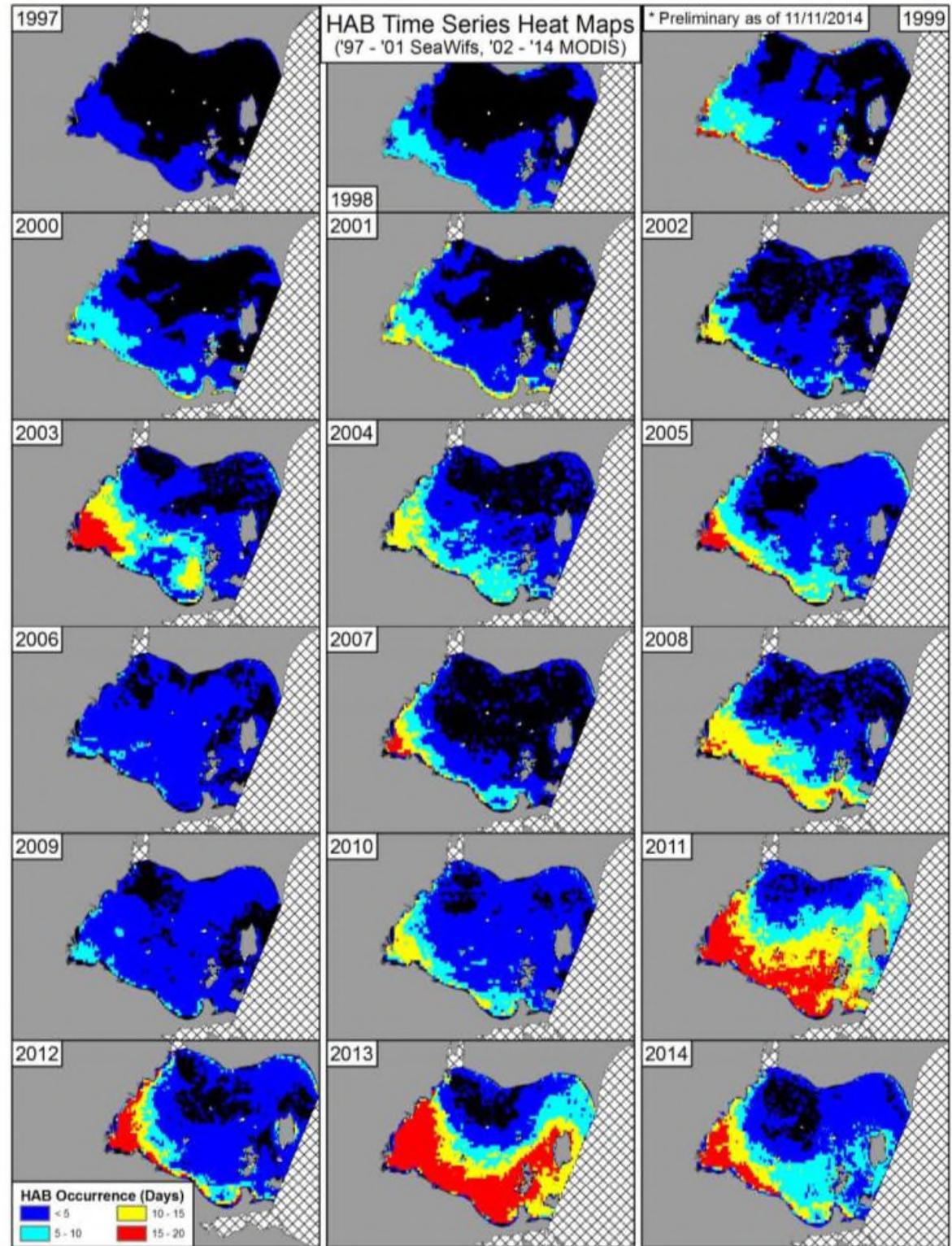
- Satellite remote sensing provides valuable synoptic monitoring of harmful algal bloom events in the Great Lakes
- The two sensors most frequently used for HAB monitoring (MODIS Aqua and MERIS) were launched in 2002, yielding a relatively short time series of data
- A longer series provides more information with which to better understand the relative importance of HAB drivers and inform management decisions

Harmful Algal Bloom Mapping

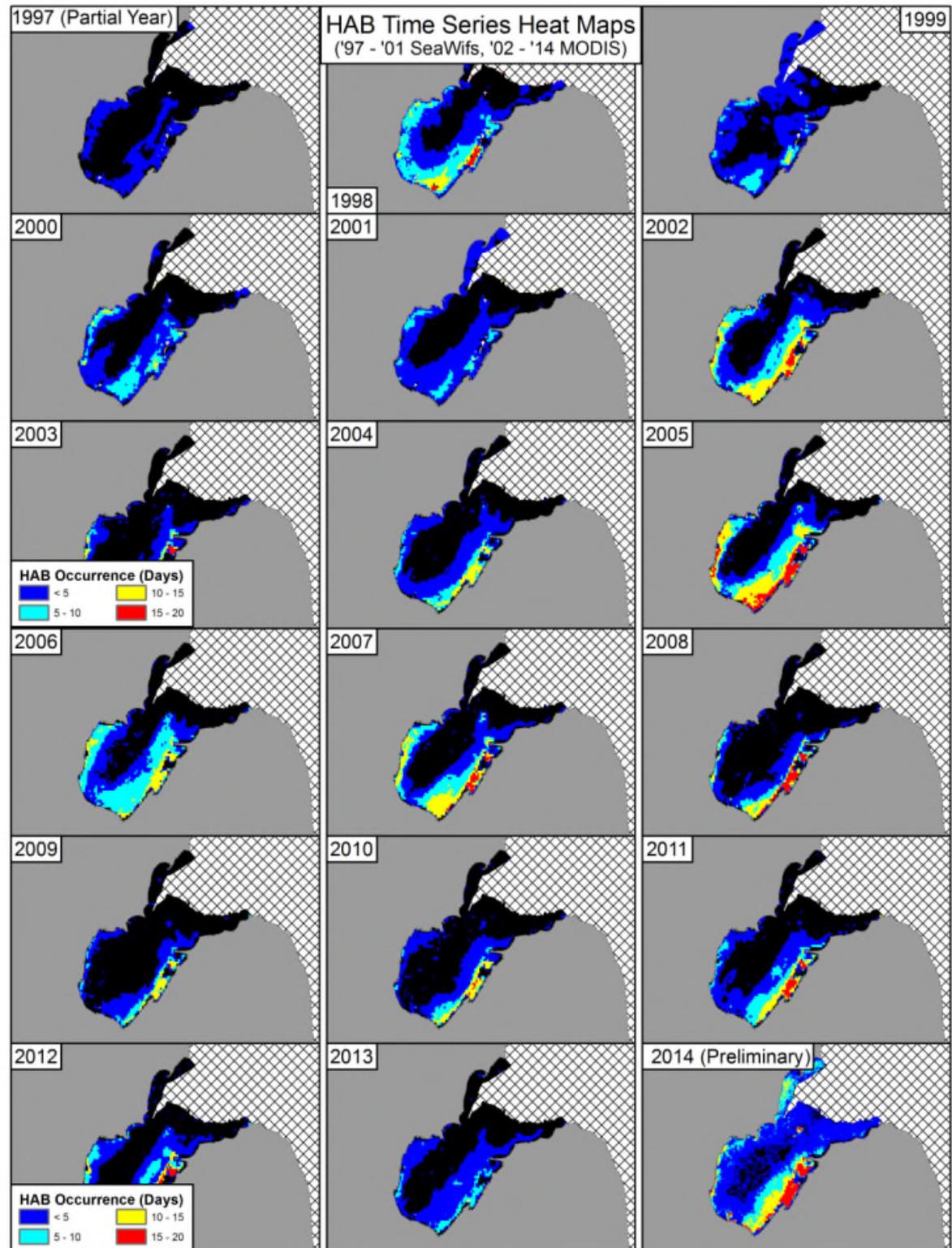
- MTRI's Multi-factor Ocean color HAB Algorithm (MOHAB) was constructed to utilize ocean color data from MODIS.
- MOHAB was previously calibrated and validated with in situ data for all five Great Lakes (Shuchman et al. 2013).
- To extend the time series, adjustments were made to the algorithm for use with SeaWiFS data.



Yearly Harmful Algal Bloom Heat Maps for Western Basin, Lake Erie



Yearly Harmful Algal Bloom Heat Maps for Saginaw Bay, Lake Huron



SAV Mapping

- *Cladophora* is a native green alga
 - Grows on solid substrate
 - In all Great Lakes (sparse in Lake Superior).
- Avian botulism associated with detached washed up *Cladophora*.
- Was a problem in the 1970s due to high levels of phosphorus.
- Great Lakes Water Quality Agreement reduced phosphorus loadings to lessen nuisance *Cladophora*.
- Nuisance growth a problem again due to effects of invasive mussels.
- More light is able to reach deeper allowing *Cladophora* & other SAV to grow
- Mussel “colonies” create areas of hard substrate where *Cladophora* can grow.



SAV Mapping Algorithm

- At-sensor radiance for each satellite band is corrected for effect of varying water depth

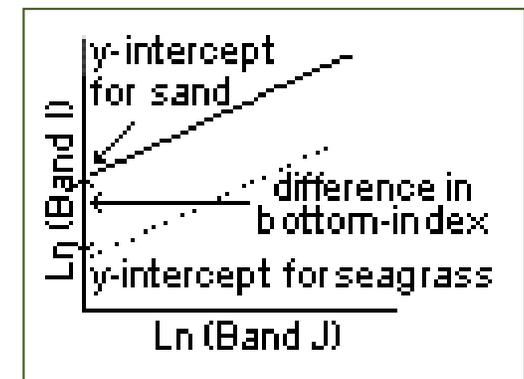
$$X_j = \ln(L - L_s)$$

- L = Upwelling radiance
- L_s = Upwelling radiance in water of 'infinite' depth

- Eliminates radiance due to the water column, leaving upwelling radiance due to bottom component.

- By taking the ratio of depth-corrected radiance between two spectral bands, we can discriminate between bottom types (sand, mud, sparse and dense SAV)

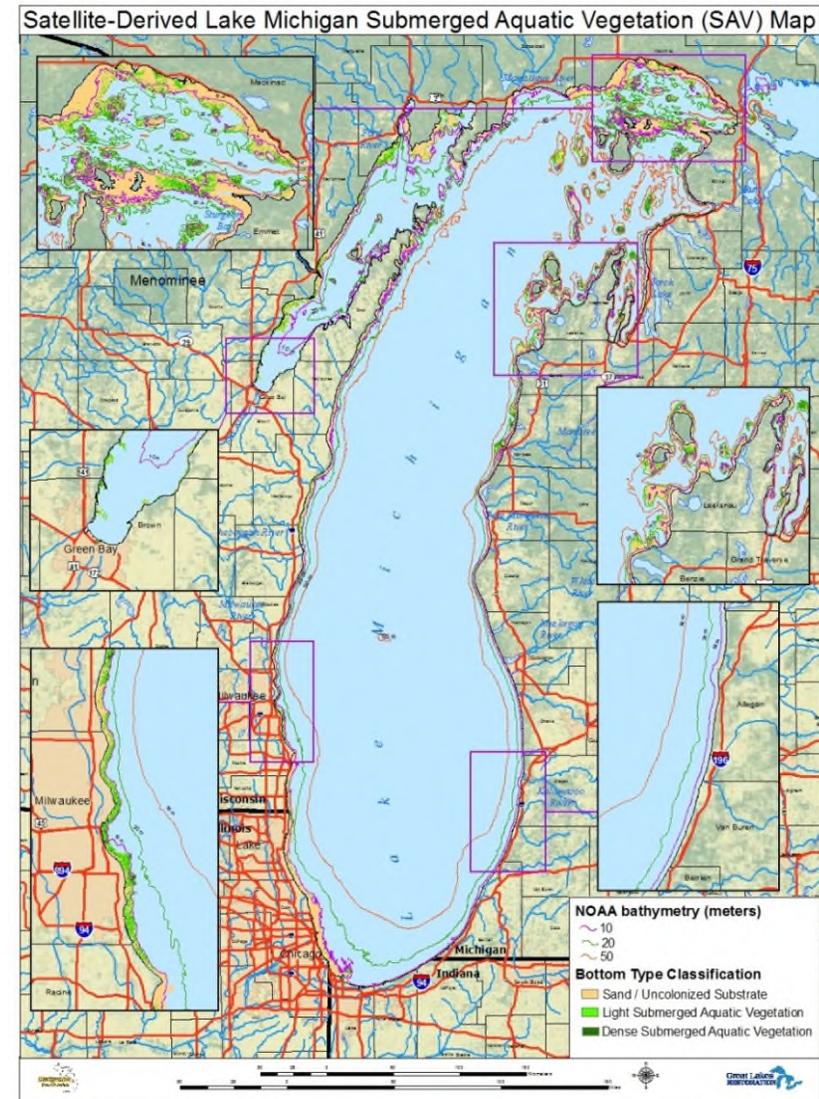
- Applied to Landsat TM and ETM+



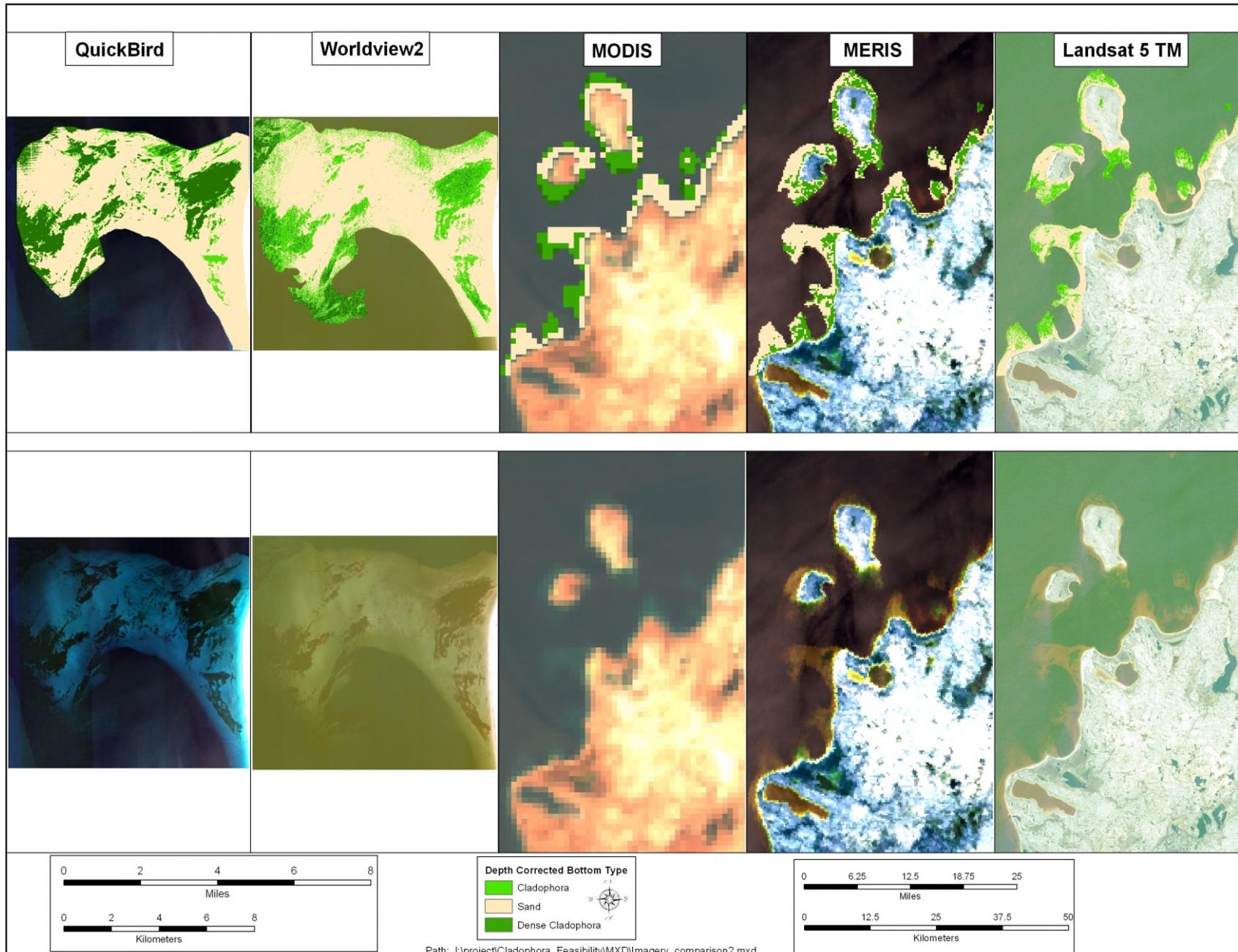
Basin-wide Nearshore SAV Map

- The SAV mapping algorithm was used to generate ca. 2010 baseline maps of SAV extent for the lower four Great Lakes
- Mapping depth varied based on lake clarity

Lake	Mean Optical Depth (m)	Maximum Optical Depth (m)
Michigan	12	>20
Huron	9	20
Erie	4	7
Ontario	6	9



Multi-scale SAV Mapping Capability



SAV mapping data access

Satellite-Derived Great Lakes Submerged Aquatic Vegetation Classification Map

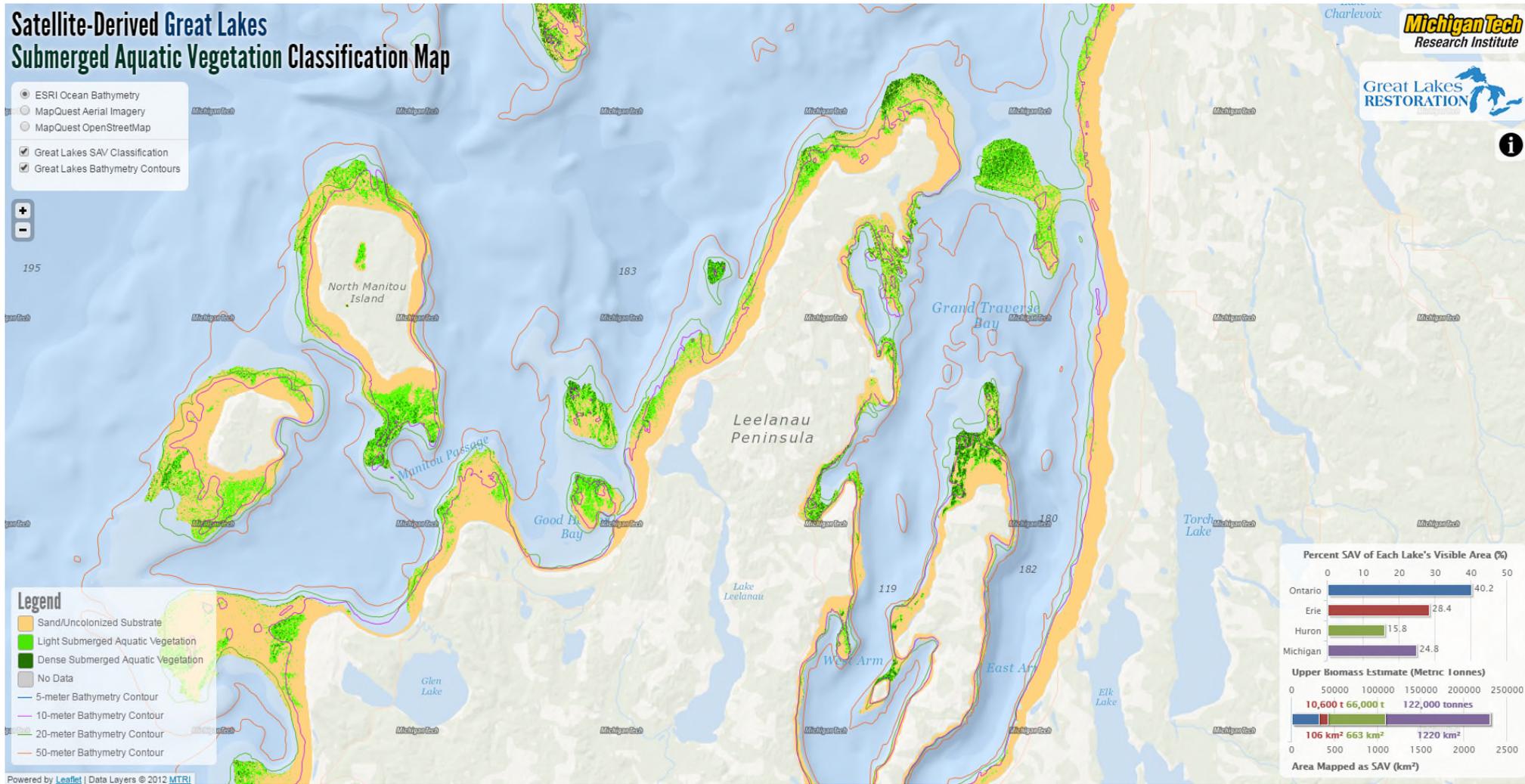
- ESRI Ocean Bathymetry
- MapQuest Aerial Imagery
- MapQuest OpenStreetMap
- Great Lakes SAV Classification
- Great Lakes Bathymetry Contours



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- Legend**
- Sand/Uncolonized Substrate
 - Light Submerged Aquatic Vegetation
 - Dense Submerged Aquatic Vegetation
 - No Data
 - 5-meter Bathymetry Contour
 - 10-meter Bathymetry Contour
 - 20-meter Bathymetry Contour
 - 50-meter Bathymetry Contour

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<http://geodjango.mtri.org/static/sav/>

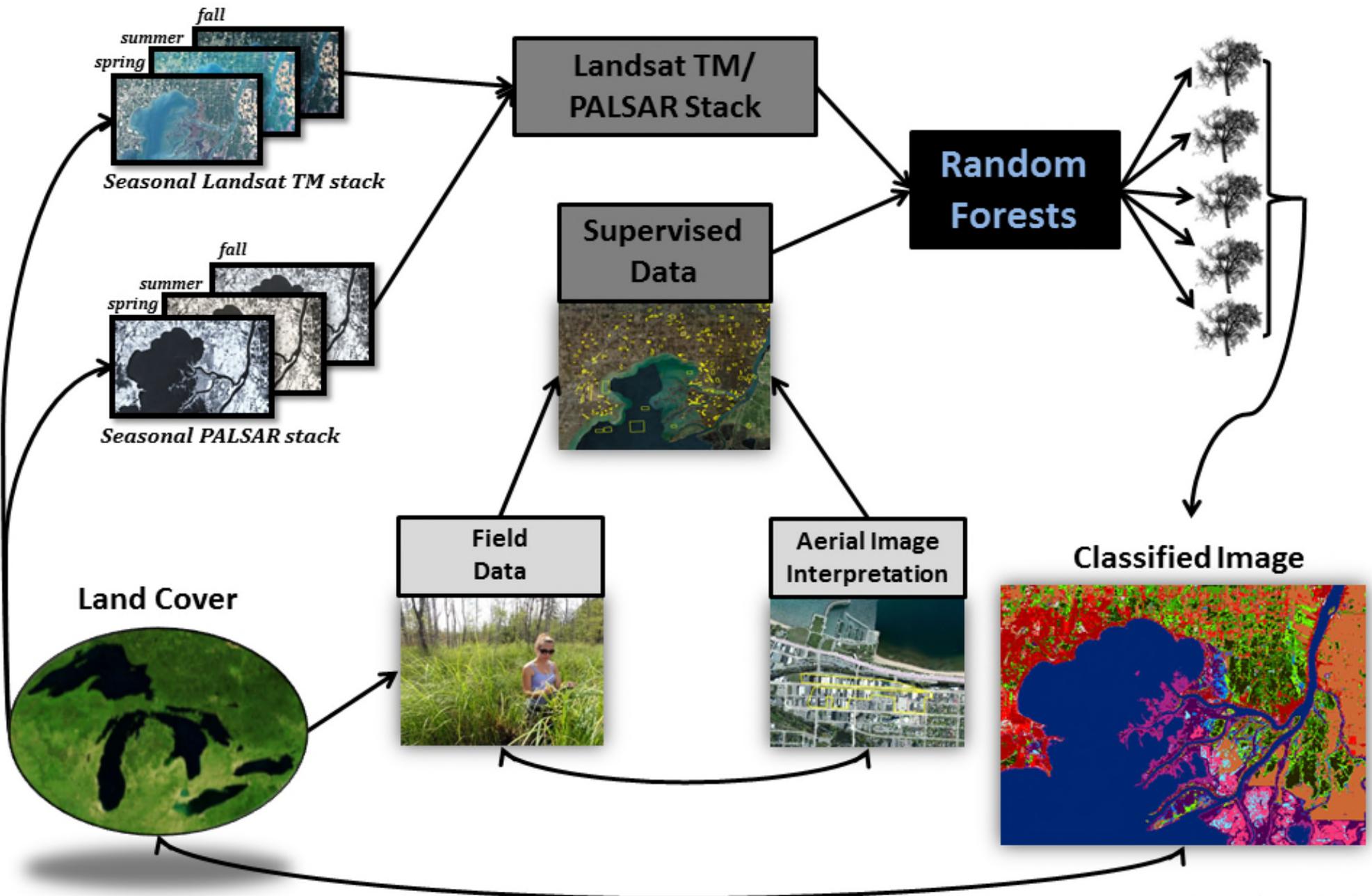


Great Lakes Coastal Wetland Mapping Project Overview

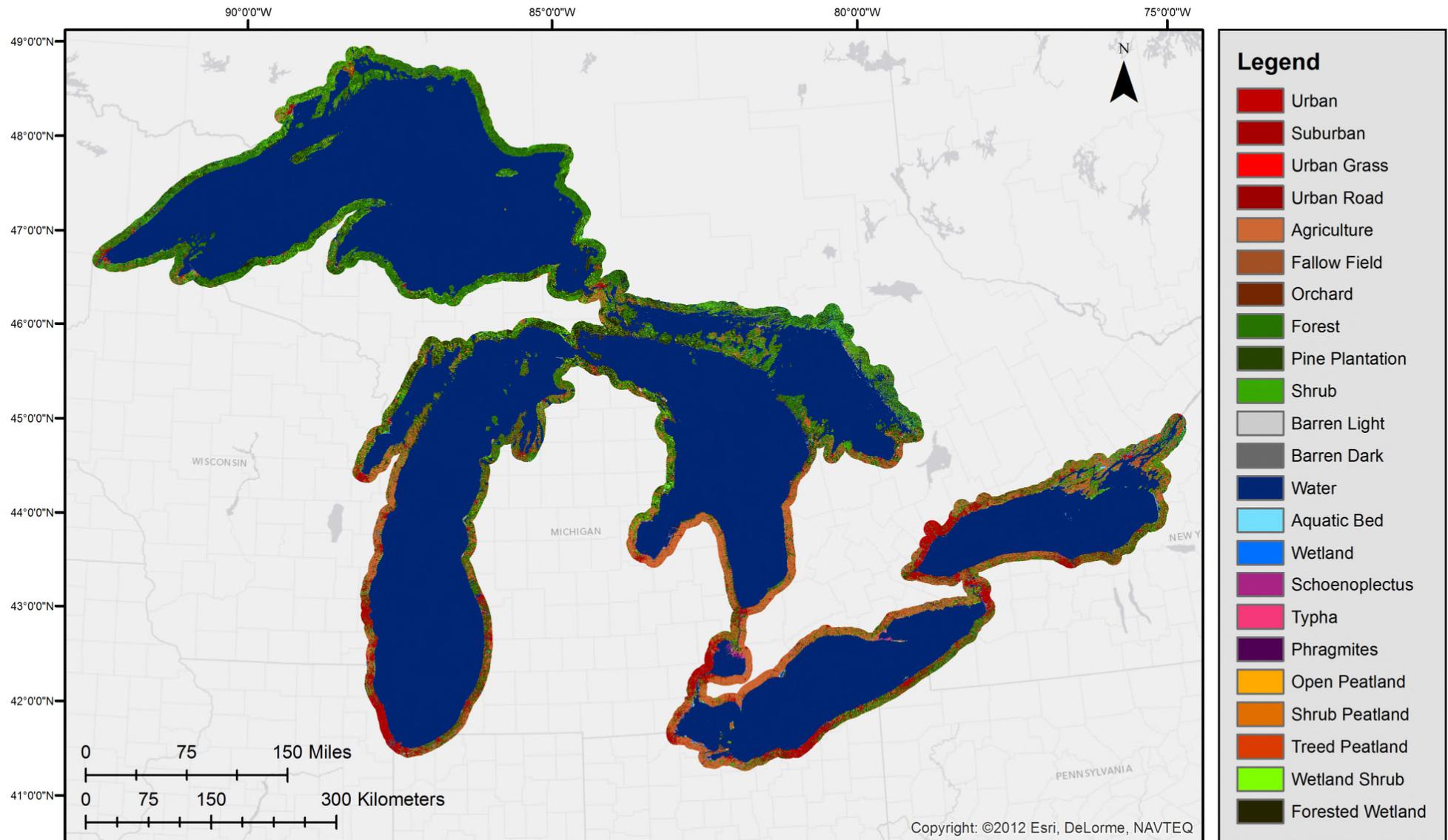
- **Project goal:** Create a comprehensive map of the entire U.S. and Canada Coastal Great Lakes and adjacent land areas
 - Develop repeatable mapping and monitoring techniques that allow for accurate classification of Great Lakes coastal wetlands

- **Approach:**
 - Use techniques developed for landscape indicator protocol under the 2004 Great Lakes Coastal Wetlands Consortium Pilot Study (Bourgeau-Chavez *et al.* 2008)
 - Data fusion approach utilizing moderate resolution (20-30 m) satellite remote sensing from Optical and Synthetic Aperture Radar (SAR) sensors
 - PALSAR L-band HH and HV polarization (20 m resolution)
 - Landsat TM optical-IR (30 m) / thermal (120 m resampled to 30 m)
 - Use Multi-season data (Spring, Summer and Fall)

Great Lakes Coastal Wetland Mapping

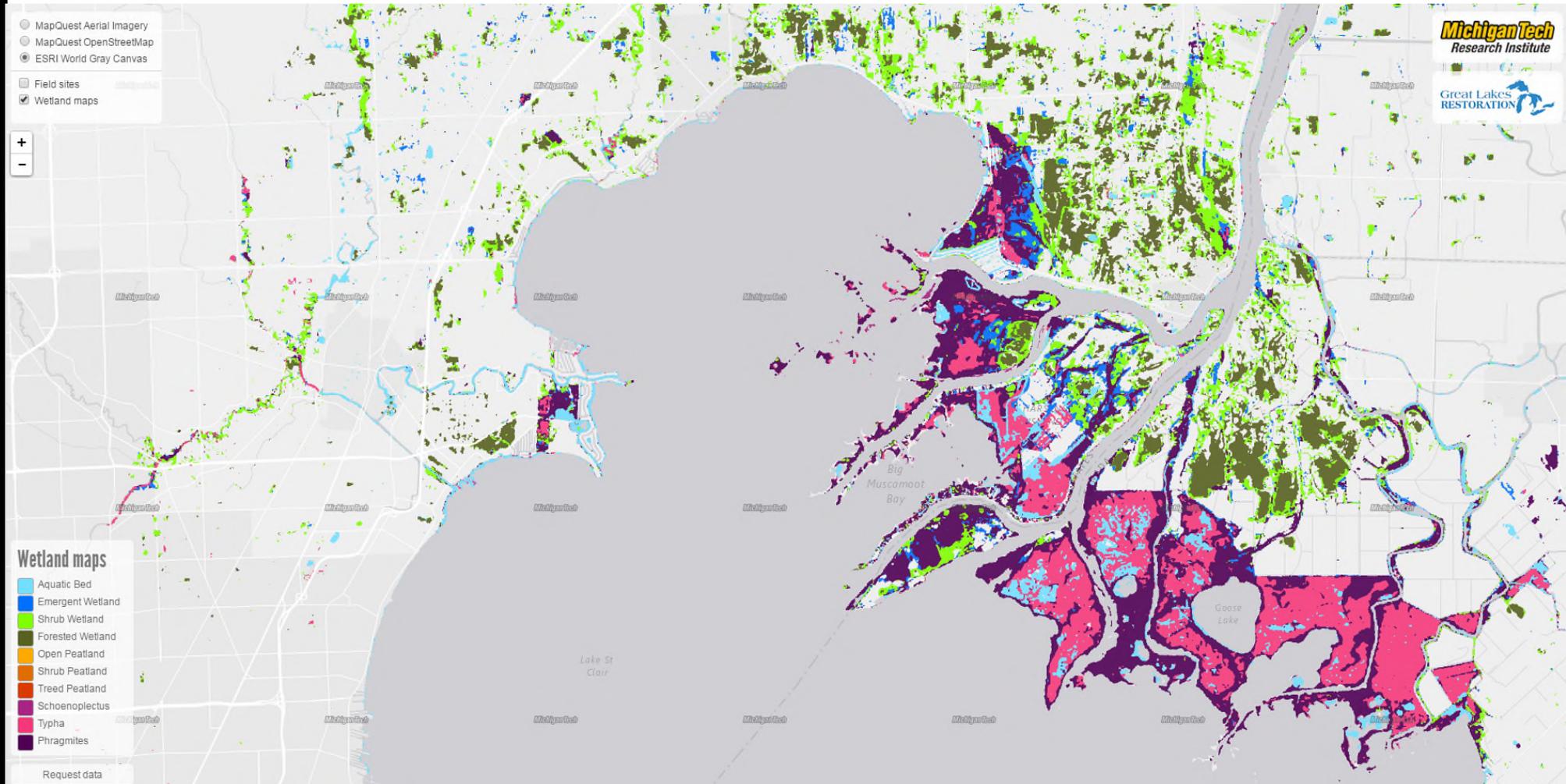


Great Lakes Coastal Wetland Mapping





Great Lakes Coastal Wetland Mapping Data Access



<http://geodjango.mtri.org/coastal-wetlands/>

Phragmites adaptive management

Remote Sensing/GIS

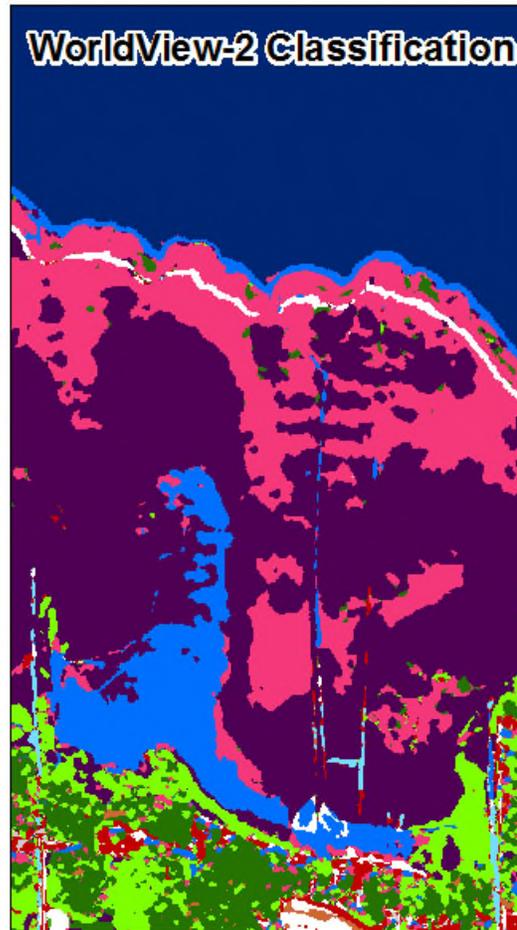
1. What is the current *Phragmites* distribution?
2. Where are the leading edges?
3. Where have past-treatments occurred?
4. What was the effectiveness of past treatments (i.e. where is there regrowth/standing dead, what other species have come in post-treatment)? Has the habitat been restored?

} Remote Sensing/
Field Monitoring

Adaptive Management

5. What is the definition of success?
6. What other factors drive the invasion and/or inhibit effectiveness of treatment and can these be mitigated?

Multi-scale Coastal Wetland Mapping



Classes

-  Urban
-  Suburban
-  Urban Grass
-  Urban Road
-  Agriculture
-  Fallow Field
-  Forest
-  Shrub
-  Barren
-  Water
-  Aquatic Bed
-  Emergent Wetland
-  Schoenoplectus
-  Typha
-  Phragmites
-  Wetland Shrub
-  Forested Wetland

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0 0.125 0.25 0.5 Miles



Recap

- Remote Sensing can be used for a variety of water quality related applications.
- Unable to replace field measurements, but provide an acceptable method to monitor, especially with limited time/budget/manpower.
- Making derived products available to researchers and the public is a top priority.

Questions?

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