CoastWatch Satellite Research and Product Development

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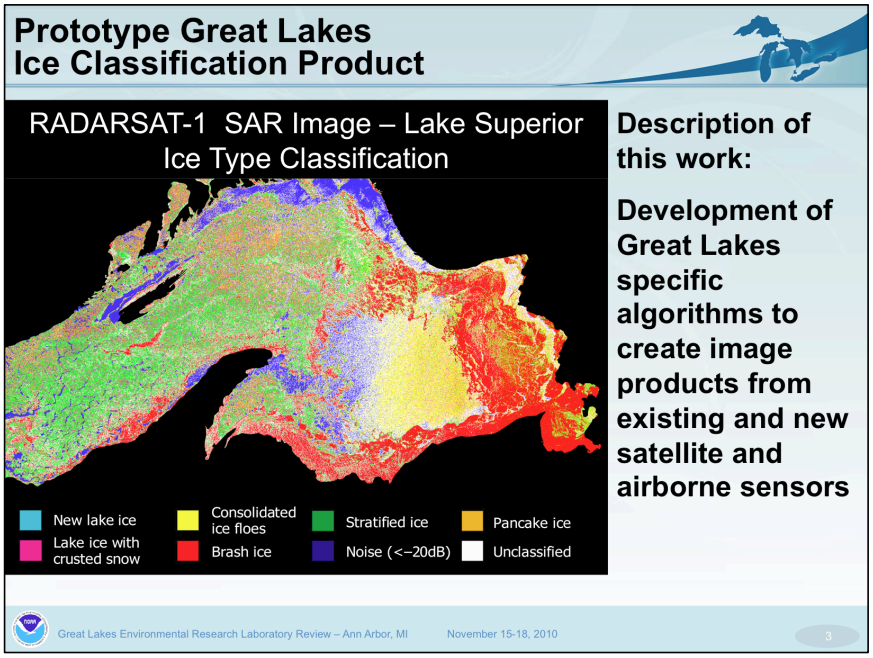
Need for Great Lakes Satellite Research

Great Lakes specific algorithms are needed for satellite retrieval of key parameters owing to several factors:

- Ocean algorithms do not work well in time or space on the Great Lakes
- No developed ocean algorithms to retrieve the parameters we need
- Vast difference in resolution and spatial coverage needs
- Freshwater vs. saltwater

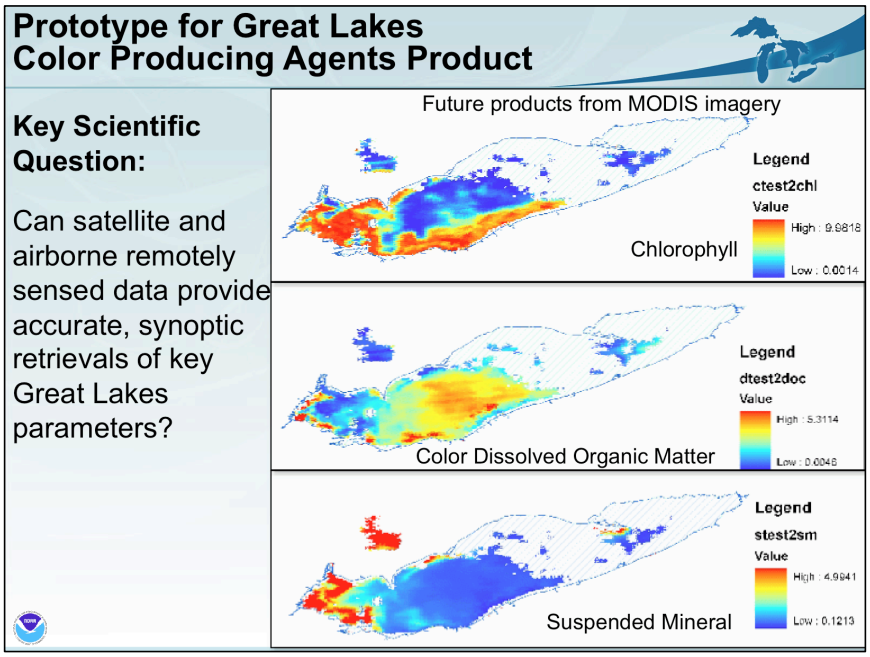
Why satellite research in the Great Lakes?
Key parameters include: ice type / thickness, chlorophyll, Chromophoric Dissolved Organic Matter (CDOM), sediment, wind speed / direction, Harmful Algal Bloom (HAB) development, etc.
Each question will be illustrated by an example of a prototype product developed or in-development in the presentation

Image: RADARSAT II



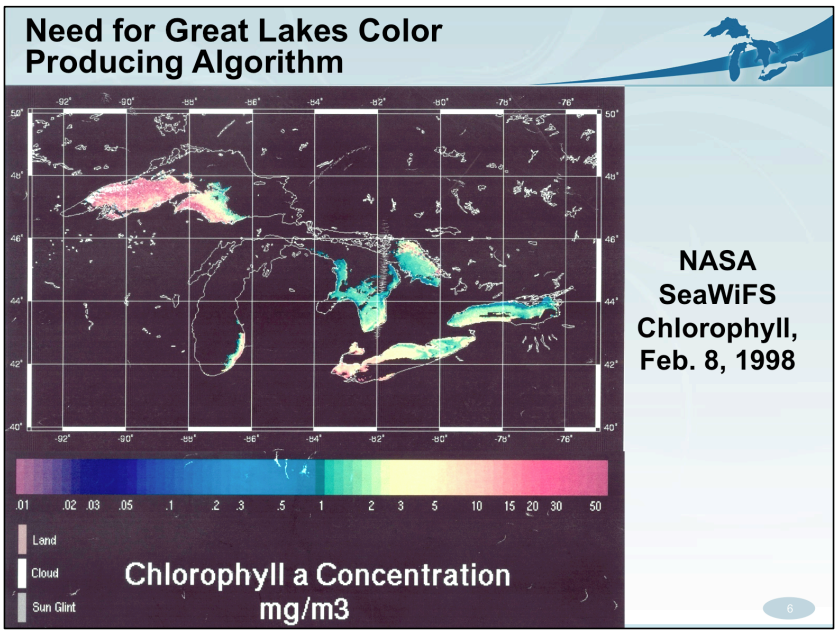
RADARSAT-1 is a sophisticated Earth observation satellite developed by Canada to monitor environmental changes and the planet's natural resources. Launched in November 1995.

SAR: Synthetic Aperture Radar
Citations:
Leshkevich, G.A. and S.V. Nghiem, 2007. Satellite SAR Remote Sensing of Great Lakes Ice Cover Part 2. Ice Classification and Mapping. *J. Great Lakes Res.*, 33(4):736-750.
Nghiem, S.V. and G.A. Leshkevich, 2007. Satellite SAR Remote Sensing of Great Lakes Ice Cover, Part 1. Ice Backscatter Signatures at C-Band. . *J. Great Lakes Res.*, 33(4):722-73.



NASA operated MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard the Terra (EOS AM) and the Aqua (EOS PM) satellites.

Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths.

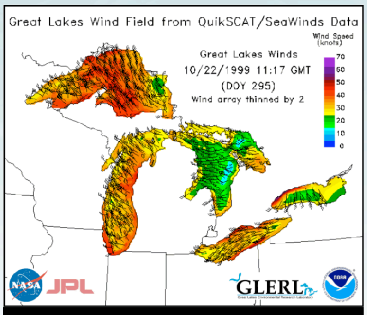


Why do we need remote satellite products in the Great Lakes?
In the above example of a NASA SeaWiFS ocean color data image: red in western third of Lake Superior indicates very high concentrations of Chlorophyll a. This is wildly inaccurate. Lake Superior is very oligotrophic , the chlorophyll concentrations calculated by the ocean algorithm are wrong. Black areas are the cloud cover.
The purpose of the Sea-viewing Wide Field-of-view Sensor (SeaWiFS) Project is to provide quantitative data on global ocean bio-optical properties to the Earth science community. Subtle changes in ocean color signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications.

Prototype of CoastWatch Great Lakes Wind Product

What are the specific products and/or services resulting from this work?

- **High resolution scatterometer winds**
- **Scatterometer ice mapping**
- **Synthetic aperture radar (SAR) ice classification and mapping**
- **Ice thickness mapping**
- **Satellite retrieval of chlorophyll, CDOM, and suspended mineral**
- **Early HAB detection (hyperspectral)**
- **Others**



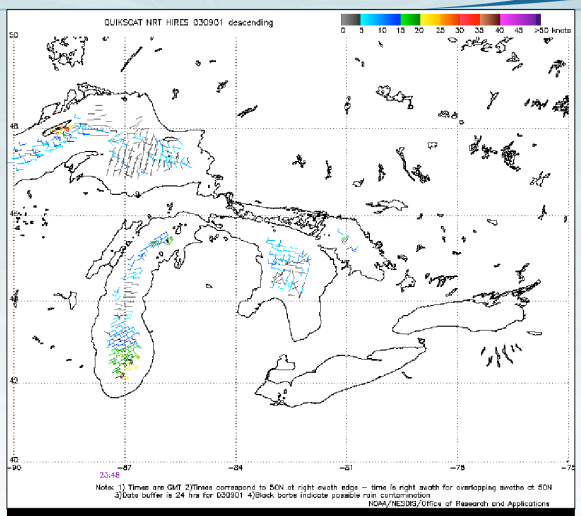
Prototype of Great Lakes wind-field product derived from QuikSCAT/ SeaWinds Data

This is an example of a completed product awaiting transition to operations.
The wind retrieval methodology used to estimate high-resolution (12.5 km) wind fields over the Great Lakes differs from the standard approach in three important ways:

- QSCAT range-compressed measurements (called slice data) with a higher resolution of 7 km by 25 km are used rather than the full antenna footprint of 25 km by 35 km. QuikSCAT is a polar orbiting satellite with an 1800 km wide measurement swath on the earth's surface. Generally, this results in twice per day coverage over a given geographic region.
- Apply land flagging so that any measurement with its centroid over water is included in the wind retrieval processing.
- A direction interval retrieval algorithm (DIR) is used to improve directional accuracy of QSCAT wind vectors for sub-optimal viewing conditions.
- Process to obtain wind vectors on a 12.5-km wind field grid instead of the 25-km grid produced by standard processing and validate with GLCFS nowcast winds fields and buoy data.

Nghiem, S.V., G.A. Leshkevich, and B.W. Stiles. 2004. Wind Fields Over the Great Lakes Measured by the Sea Winds/QuikSCAT Scatterometer. *J. Great Lakes Res.*, 30(1): 148-165.

Need for Great Lakes Wind Product



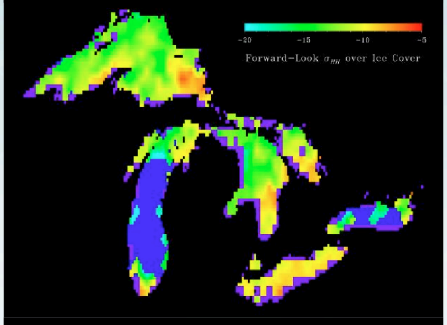
Great Lakes Wind Field from QuikSCAT/SeaWinds

Product from NOAA NESDIS Office of Research and Applications is not well suited for the Great Lakes because they are using native 25x35 km resolution, which means that when you take into account land contamination, at that resolution you don't get any data from Lake Erie or Lake Ontario. The areas around the edge of the lakes result from "land contamination".

Users of Great Lakes CoastWatch Products

- Supports GLERL internal research projects
- Supports operational mandates within NOAA and sister agencies
- Supports Regional users via the NOAA CoastWatch Great Lakes Node
  - Environmental science
  - Decision making
  - Supporting research
- Supports educational and recreational activities

Mapping of Great Lakes Ice Cover for 2/27/2003



Prototype of QuikSCAT Ice Cover Product for the Great Lakes

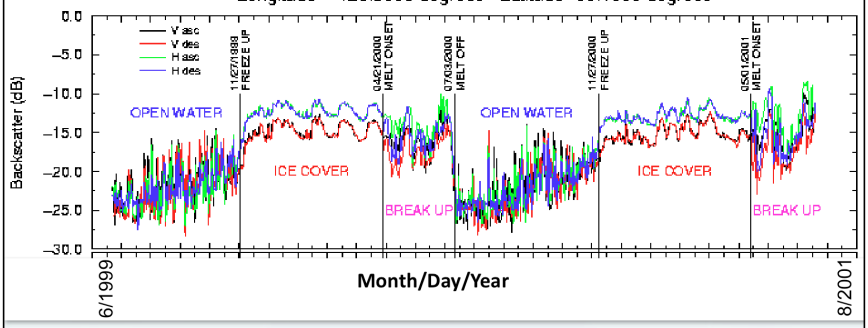
Supports internal research projects and operational mandates, in addition to distribution to the regional user community via the NOAA CoastWatch Great Lakes Node in support of environmental science, decision making, and supporting research as well as educational and recreational activities.

Nghiem, S.V. and G.A. Leshkevich, Using Satellite Scatterometer Data for Great Lakes Ice Mapping and Climate Change Detection, *International Journal of Remote Sensing*, (in preparation).

QuickSCAT Scatterometer Application to Climate Research

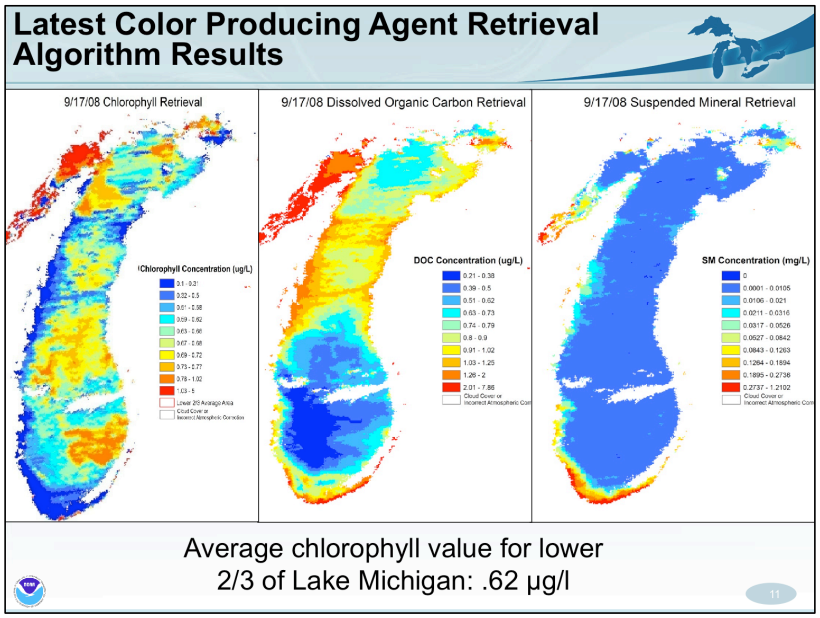
Station LAKE00 : GREAT BEAR LAKE (North), CANADA

Longitude=-120.5000 degrees Latitude=66.1000 degrees



Using this data, the dates of ice freeze-up and break-up can be determined -- useful for regional climate change analysis.

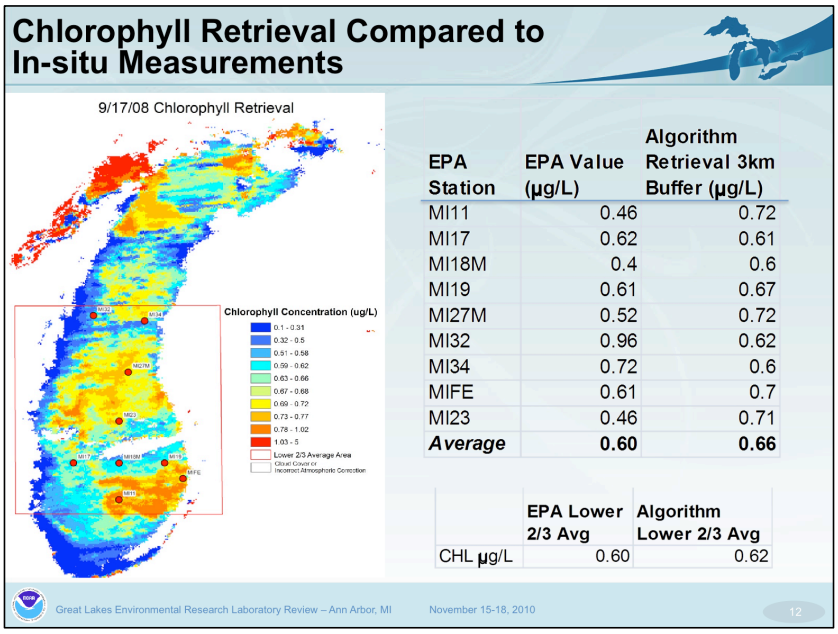
Dates of ice cover freeze up and break up are important parameters in climate change research.



- Latest iteration of Color Producing agent algorithm
- GLERL's retrieval algorithm can retrieve all Color Producing Agents from the same satellite image
- The parameters above are of value to ecosystem research.

Pozdnyakov, D. et al., 2005. Operational algorithm for the retrieval of water quality in the Great Lakes. *Remote Sensing of Environment*, 97:353-370.
Shuchman, R. et al., 2006. Verification and Application of a Bio-Optical Algorithm for Lake Michigan Using SeaWiFS: A Seven Year Interannual Analysis. *J. of Great Lakes Res., 32*(2):258-279.

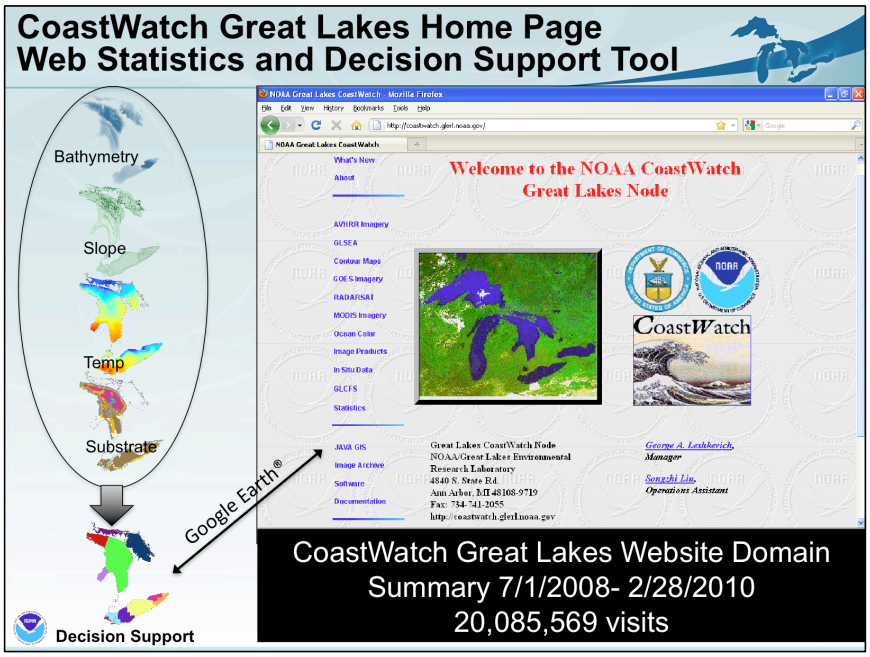
O'Donnell, D.M., S.W. Effler, C.M. Strait, and G.A. Leshkevich, Optical characterizations and pursuit of optical closure for the western basin of Lake Erie through in situ measurements. *J. of Great Lakes Res.*, (in press).



EPA Station	EPA Value (µg/L)	Algorithm Retrieval 3km Buffer (µg/L)
MI11	0.46	0.72
MI17	0.62	0.61
MI18M	0.4	0.6
MI19	0.61	0.67
MI27M	0.52	0.72
MI32	0.96	0.62
MI34	0.72	0.6
MIFE	0.61	0.7
MI23	0.46	0.71
Average	**0.60**	**0.66**

	EPA Lower 2/3 Avg	Algorithm Lower 2/3 Avg
CHL µg/L	0.60	0.62

- Using new HO model results in retrievals that produce concentration values within the ranges reported by the EPA from in situ sampling
- Average chlorophyll values for the lower 2/3 of Lake Michigan match published values within 5%
- Satellite derived transect from West to East consistent with published data
- Individual sample point comparison, although over a month apart (August to September), agree **within 10%**
- NASA protocol is within 30%
- According to biologists, there is negligible difference between August and September biologically, unless there is an episodic event, GLERL researchers were sampling in southern Lake Michigan during those months, no episodic events observed.

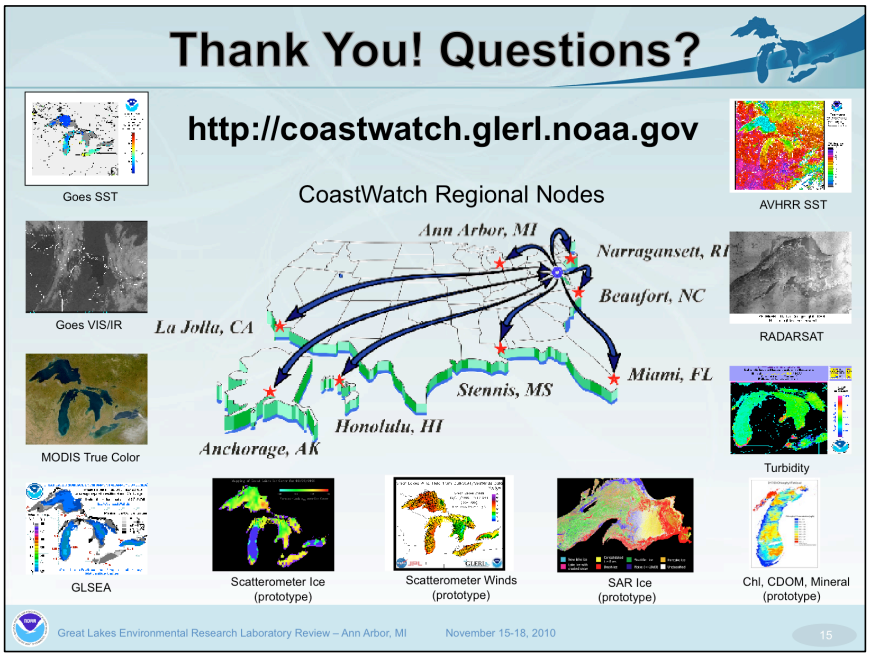


The Great Lakes CoastWatch Node is publically available at: coastwatch.glerl.noaa.gov. The node has received over 20 million visits in 1½ years.

A new decision support tool is being developed to allow interactive retrieval of GIS-based habitat databases that can be mapped and queried using Google Earth®. Additional decision support programs which facilitate coastal marine spatial planning will be distributed through the CoastWatch Great Lakes node. Edward Rutherford will talk more about this in his presentation.

Collaborators

- National Aeronautics and Space Administration
  - Goddard Space Flight Center
  - GLENN Research Center
- Jet Propulsion Laboratory
- Michigan Tech Research Institute
- Nansen International Environmental and Remote Sensing Center, St. Petersburg
- Upstate Freshwater Institute
- Cooperative Institute for Limnology and Ecosystem Research
- U.S. Coast Guard
- Canadian Coast Guard
- Environmental Protection Agency
- NOAA National Environmental Satellite, Data, and Information Service



GLERL is the regional CoastWatch node for the Great Lakes.

Map depicts the connectivity between the National Environmental Satellite Data and Information Service (CoastWatch Central node) and the other nodes.