Illustrations include (left to right) satellite SAR ice type classification, phragmites mapping, primary productivity, UAS in situ measurements, satellite color producing agent (CPA) retrievals, ship-based sonar measurements, airborne lidar measurements.

This work aligns with the following NOAA Goals:

**Science: Climate Adaptation and Mitigation**
Improved scientific understanding of the changing climate system and its impacts

**Science: Weather-Ready Nation**
Improve freshwater resource management
Improve transportation efficiency and safety

**Science: Healthy Oceans**
Improved understanding of ecosystems to inform resource management decisions

**Science: Resilient Coastal Communities and Economies**
Comprehensive ocean and coastal planning and management
Safe, efficient and environmentally sound marine transportation
Improved coastal water quality supporting human health and coastal ecosystem services

**Education: Science-Informed Society**
Youth and adults from all backgrounds improve their understanding of NOAA-related sciences by participating in education and outreach opportunities
Formal and informal educators integrate NOAA-related sciences into their curricula, practices, and programs

**Education: Organizational Excellence**
NOAA develops and supports a coordinated portfolio of products, programs, and partnerships that improves education opportunities in NOAA-related content areas for underserved audiences
Need for Great Lakes Satellite Research

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

- Ocean algorithms often do not work well in time or space on the Great Lakes
- Ocean algorithms often are not tuned to the parameters we need (e.g. ice types)
- Vast difference in resolution and spatial coverage needs
- Freshwater vs. saltwater
Currently transferring Great Lakes ice type classification algorithm to NOAA NESDIS for evaluation to produce operationally for the Great Lakes.
Methodology for Great Lakes Ice Classification Prototype

Great Lakes Winter Experiment
Jet Propulsion Lab Scatterometer used on USCGC Mackinaw

USCGC Mackinaw in Whitefish Bay

Library of backscatter signatures from different ice types on Lake Superior measured using Jet Propulsion Lab C-band scatterometer during Great Lakes Winter Experiment.
Chlorophyll retrieval algorithms found not to work well in the Great Lakes in time or space. Our CPA algorithm is based on hydro-optical models of the Great Lakes. The Visible Infrared Imaging Radiometer Suite (VIIRS) collects visible and infrared imagery and radiometric measurements of the land, atmosphere, cryosphere, and oceans. CDOM = color dissolved organic matter.
These two plots summarize the performance of the completed CPA-A algorithm for the upper three Great Lakes (Lakes Superior, Michigan, Huron). The plot on the right utilized 156 independent in situ chlorophyll measurements compared to near simultaneous CPA-A chlorophyll retrievals (+/- 2 days). The plot indicates the robust performance of the CPA-A in both nearshore and offshore locations. The plot on the left is the NASA standard OC3 chlorophyll retrievals for the same dataset. Note the reduced performance of the OC3 and inability to successfully retrieve all 156 locations.

The two plots further confirm the supposition that ratiing chlorophyll retrieval approaches can work relatively well in open water areas of the Great Lakes but do not perform well in Lakes Erie, Ontario, or nearshore environments. (optically complex waters)
Currently transferring CPA algorithm to NOAA NESDIS for evaluation to produce operationally for the Great Lakes.
A radar scatterometer is designed to determine the normalized radar cross section (sigma-0) of the surface. Scatterometers operate by transmitting a pulse of microwave energy towards the Earth’s surface and measuring the reflected energy.
Users of Great Lakes CoastWatch Products

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

Application to Climate Research

Station LAKE00 : GREAT BEAR LAKE (North), CANADA

[Graph showing data]

Using scatterometer data, the dates of ice freeze-up and break-up can be determined – useful for regional climate change analysis.
Measuring Light Transmittance Through Ice Cover

**Application to Under Ice Ecology (Winter Primary Productivity)**

Light Attenuation Through Snow Ice on Lake Ice With and Without a Snow Cover

<table>
<thead>
<tr>
<th>Hole</th>
<th>Ice Type and Picture</th>
<th>Irradiance Curves</th>
<th>% Light Transmitted through Ice (400-700 nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL_1</td>
<td>Snow ice with snow on top</td>
<td><img src="image1.png" alt="Irradiance Curves Image" /></td>
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<tr>
<td>DL_1</td>
<td>Snow ice with no snow on top</td>
<td><img src="image2.png" alt="Irradiance Curves Image" /></td>
<td>23.6</td>
</tr>
</tbody>
</table>

Lake Superior ice types - March 28, 2014 from RADARSAT-2 Ice type classification maps can be matched with average transmission loss for each ice type to produce maps of lake-wide light transmission.

10/10
New upwelling classification algorithm for the Great Lakes can identify and map upwellings important to fisheries management and research.
At request of the Coast Guard, demonstration of drone (quad-copter) capability for real-time ice reconnaissance in support of Coast Guard ice breaking operations. Demonstration aboard the USCGC Mackinaw in the Straits of Mackinac and Green Bay during March 1-3, 2016. A video camera was used to send real-time imagery to the bridge of the USCGC Mackinaw. Other sensors, such as a ground penetrating radar (GPR) for transects of ice thickness, may be used depending on the size and capability of the drone.
CoastWatch Great Lakes Home Page with Planned Decision Support Tool

CoastWatch Great Lakes Website Domain
Collaborators

- National Aeronautics and Space Administration (NASA)
  Goddard Space Flight Center
  GLENN Research Center
- Jet Propulsion Laboratory (JPL)
- Michigan Tech Research Institute (MTRI)
- Nansen International Environmental and Remote Sensing Center, St. Petersburg (NIERSC)
- Upstate Freshwater Institute (UFI)
- Cooperative Institute for Limnology and Ecosystem Research (CILER)
- U.S. Coast Guard (USCG)
- Canadian Coast Guard (CCG)
- Environmental Protection Agency (EPA)
- NOAA National Environmental Satellite, Data, and Information Service (NESDIS)
Questions?

http://coastwatch.glerl.noaa.gov

NOAA CoastWatch Regional Nodes

Goes SST

Goes VIIRS

MODIS True Color

GLSEA

Scatterometer Ice (prototype)

Scatterometer Winds (prototype)

SAR Ice (prototype)

AVHRR SST

VHRS 927

RADARSAT

Turbidity

Oil, CDOM, Mineral (prototype)
<table>
<thead>
<tr>
<th>Project/Product (Transition Partner)</th>
<th>Technical Readiness Level (TRL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODIS/VIIRS (CoastWatch)</td>
<td>6</td>
</tr>
<tr>
<td>OLI for Classification (CoastWatch)</td>
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</tr>
<tr>
<td>Hyperspectral HLA detection (LHAR, CO-OPS)</td>
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<tr>
<td>AR Ice - Coast Guard (Coast Guard)</td>
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<tr>
<td>Hyperspectral Classification ( Sustainability) (CO-OPS)</td>
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<tr>
<td>Hyperspectral HLA mapping (LHAR, RMBF, CO-OPS)</td>
<td>2</td>
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<tr>
<td>LHRA (Coast Guard)</td>
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<tr>
<td>NWS AL stations (NWS, ARS)</td>
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<tr>
<td>NWS All Current Observations (NWS DA-NPS)</td>
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<tr>
<td>NCOM 2016/17 SCISAF/SHARE (NLSR, NWS, NCOM)</td>
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<tr>
<td>NCOM Coastal Observations (NDBC, OKE)</td>
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<tr>
<td>Hyperspectral System (NMMB, Cleveland Water Dept.)</td>
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<tr>
<td>Nudbeck Diary Network (NMMB, CO-OPS)</td>
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<tr>
<td>Skogars Mollers (GLERL, Ecodyne)</td>
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<tr>
<td>Imaging, Acoustics (GLERL, Ecodyne)</td>
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</tr>
</tbody>
</table>

**Technical Readiness Level (TRL) Definitions**

1. Basic principles have been demonstrated.
2. Conceptual and/or application has been formulated.
3. Analytical and experimental critical function and/or characteristic point of concept.
4. Concept/technology validated in laboratory environment.
5. Concept/technology validated in operational environment.
6. System/subsystem model or prototype demonstrating in a relevant test or environment.
7. System prototypes demonstrating in operational environment.
8. A system completed and "mission qualified" through full scale tests in test environment.
9. A system completed and "mission proven" through successful operations.