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Commentary

Developing a Great Lakes remote sensing community

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Introduction

Observational data collection of the Laurentian Great Lakes has advanced during the past decade to such a level as to allow real-time analysis from moorings and near real-time from satellite data. Ocean color satellite-based remote sensing provides a rich data set that when properly analyzed allows for the generation of geospatial maps of chlorophyll, dissolved organic carbon, suspended minerals, harmful algae blooms (HABs), surface plumes, benthic vegetation communities, primary productivity (pp) and optical water properties (extinction coefficient (kd), photosynthetically active radiation (PAR) and photic zone depth) on a 2 m to 1 km grid dating back in some cases to the early 1970s. Microwave satellite sensors such as synthetic aperture radar (SAR) and scatterometers provide near real-time information on lake ice cover, winds and waves. Multi-temporal Landsat and ALOS PALSAR satellite data are also being used in the Great Lakes to map wetlands and invasive plants within these coastal areas. Airborne LiDARs also provide useful nearshore water depth and bottom type mapping in Great Lakes waters. Making the most of such improvements in the historical Great Lakes dataset will require diligence and a comprehensive strategy, with recognition of the importance of open collaboration in developing a regional working strategy for remote sensing technologies, sensor data applications, and the data management methods that will integrate the technologies within regional and global observation systems.

The IOOS/Great Lakes Observing System (GLOS), in collaboration with NOAA/GLERL, and in conjunction with the ongoing NOAA CoastWatch Great Lakes program with its stakeholders that include federal, state, local government along with the private sector and academia, can implement into operational scenarios the suite of remote sensing algorithms developed to generate meaningful Great Lakes products.

Brief history

Early aerial panchromatic images of the Great Lakes allowed the marine sciences community to observe seasonal changes along the lake coastal zones, providing a new perspective of spatial observation. After the October 1978 launch of Nimbus-7 and successful operation of the coastal zone color scanner (CZCS), satellite optical measurements of pigments and sediment became accessible. Despite the relatively coarse CZCS spatial resolution, investigators working in the coastal ocean and Great Lakes demonstrated that satellite sensors presented an enabling technology to the natural sciences and resources communities. Additionally, Leshkevich (1985) described lake ice estimates and classification during winter, demonstrating satellite data was useful for supporting regional remote sensing research year-round.

Currently, regional remote sensing applications are derived from a suite of airborne and satellite sensors that includes radar sensors aboard RADARSAT 1\2 and Envisat, and optical sensors on Landsat, SeaWiFS, MODIS, MERIS, VIIRS and HICO. Recent airborne prototype hyperspectral imager (HSI) data from NASA Glenn Research Center have also successfully shown the ability to quantify an annual harmful algal bloom (HAB) occurring in the West Basin area of Lake Erie (Lekki et al., 2009). Satellite synthetic aperture radar imagery from Radarsat-2, depending on operational mode, provides data at up to 3 m (ultra-fine resolution mode) in horizontal and vertical polarization for classifying lake ice types (Leshkevich and Nghiem, 2013–in this issue), lake-surface physical features, and using ALOS PALSAR L-band for successful identification of coastal invasive species (Bourgeau-Chavez et al., 2013–in this issue).

The CoastWatch and GLOS-funded remote sensing activities have already produced unique Great Lakes information. A primary productivity map for the entire Lake Michigan has been generated and used to estimate an annual total carbon budget for the Lake indicating it is a significant carbon sink for the area (Shuchman et al., 2013–in this issue).

Remote sensing community of practice

Current and future remote sensors for the Great Lakes were among the discussion topics at the NOAA Great Lakes Environmental Research Lab (GLERL) workshop held May 8–9, 2012, during which approximately 30 professionals from the Great Lakes region met in Ann Arbor, MI. The diverse group of attendees represented federal (NASA, NOAA, USFWS, and USGS) and state agencies (from MI, MN, PA, WI), academia (MTU-MTRI, UM-TC, UM, MSU, UW), and the non-profit organization, GLOS. Meeting topics addressed sensors and platforms, currently developed products, data distribution and management, as well as user and stakeholder needs. The meeting objective was fundamentally focused on renewing and creating professional connections among the individuals actively working in regional remote sensing research, proposing a research and applications working group, and collecting ideas for a conceptual work plan design that would form the basis for a regional remote sensing community of practice.

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A shared iterative, work plan for regional remote sensing initiatives and goals would result from this and future planned workshops, and address specific topical areas of common interest, including improved links and access to optical sensor data, transferring research products and knowledge to operational use via the NOAA CoastWatch Great Lakes Node (http://coastwatch.glerl.noaa.gov), generating new resources for the user community (forum or wiki-style portal), generating data management protocols that complies with the Data Management and Communications (DMAC) plan under IOOS via the Great Lakes Observing System (GLOS). The envisioned work plan would provide requirements guidance to space and other sponsor agencies regarding temporal and spatial remote sensing requirements at the required regional scales.

Technical and personnel requirements for the community

The population of talented professionals working in Great Lakes science and applications is experienced and highly competent, including specialists with observational science and modeling backgrounds. However, the community is relatively small and has not yet coalesced into an organized community of practice that uniformly and regularly articulates both research and user remote sensing requirements and serves as an informal peer review body for the development of user applications. In addition to observational science investigators, agencies and universities in the regional community also host several specialized modeling activities to utilize remote sensing data as an input to hydrological, hydrodynamic, and ecosystem computational models. GLERL specifically has a strong history of lake ice predictive modeling and coastal forecasting (Wang et al., 2010).

Given its relatively small funded research base the Great Lakes region is highly active in remote sensing technology, driven by public and private institution research and development (R&D) of sensors and applications. While data providers and users will continue working with satellite data supported by a diversity of in situ systems, future improvements in regional high resolution capability will logically rely on increasing access to airborne sensors, and advancing development of airborne platforms and sensors. One means for physical sciences researchers to pursue will involve collaboration with unmanned aerial vehicle (UAV) and autonomous underwater vehicles (AUV) developers traditionally operating in tactical and geo-spatial intelligence R&D.

The Great Lakes regional community must address production of applications and derived products for freshwater, rather than saltwater observations. In many ways the suites of products and tools used in oceanography have been applied to inland freshwater lakes with varying success. For observational science in the Great Lakes, investigators will use the same sensors developed for oceanographic remote sensing. Currently, optical algorithms are being developed that will rectify inaccuracies in consistent prediction of marine science parameters such as pigment, CDOM, and suspended sediment concentrations. Accurate freshwater algorithms will support real-time or near real-time image and data processing.

In order to share data and applications or transition products to operational use, a common serving protocol is also a need for the Great Lakes remote sensing community. Due to high data volumes, efficient software and parallel computing systems are needed for processing and analysis of satellite data. Also, as numerical prediction models evolve towards higher resolution with continuous data assimilation, prompt production of derived satellite data products and remote sensing data as inputs to these models will be required. Supporting timely prediction estimates for environmental events such as HABs imply the ability to process sensor data rapidly. Given the large memory requirement for running multiple algorithms on a satellite sensor pass, use of cluster computing will be essential.

Status of Great Lakes remote sensing and supporting system technologies

A successful regional remote sensing working plan when fully implemented would enhance knowledge within the Great Lakes community. Assessing how the stream of useful, easily accessible in situ sensor data meshes with other marine derived instrumentation technologies within the Great Lakes Observing System (GLOS) and IOOS data management architectures in a robust workflow has largely been accomplished by GLOS investigators. The enterprise architecture developed for GLOS was detailed during the GLERL remote sensing workshop in a presentation by Limnotech, Inc. Remote sensing system data and derived products will be included in the architecture to integrate as closely and seamlessly as possible with data from the real-time coastal observation network (RECON), a multi-year in situ sensor program based at GLERL, and other regional in situ sensors systems. Mooring data, a key to maintaining long-term, quality-assured remote sensing data is currently part of the observing system. Hourly meteorological, chemical, and physical data are available from five installations distributed throughout the three lower Great Lakes (Michigan, Huron, and Erie).

Existing remote sensing capabilities present significant opportunities

Significant advances have been made and are being made in the area of satellite based remote sensing for the Great Lakes Basin, and the observing community should be positioned to respond effectively to these opportunities. There is a shortcoming in the current ability for researchers and other regional users to access and benefit from remote sensing data. There is also a deficiency in the availability of a full suite of tools and algorithms to process the satellite data into useful derived products. Filling these shortcomings should be a priority for all Great Lakes stakeholders. The investments that have been made by NOAA and NASA in satellite infrastructure and operations needs to be fully leveraged to maximize the value of the remote sensing data to address the comprehensive monitoring needs for the Great Lakes.

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References

Bourgeau-Chavez, L., Kowalski, K.P., Carlson Mazur, M.L., Scarbrough, K.A., Powell, R.B., Brooks, C.N., Huberty, B., Jenkins, L.K., Banda, E.C., Galbraith, D.M., Laubach, Z., Riordan, K.D., 2013. Mapping invasive *Phragmites australis* in the coastal Great Lakes with ALOS PALSAR satellite imagery for decision support. J. Great Lakes Res. 39 (S1), 65–77 (Special Issue on Remote Sensing, in this issue).

Lekki, J., Leshkevich, G.A., Anderson, R., Nguyen, Q.V., Demers, J., Flatico, J., Kojima, J., 2009. Development of hyperspectral remote sensing capability for the early detection and monitoring of Harmful Algal Blooms (HABs) in the Great Lakes. AIAA Infotech Aerospace Conference, Seattle, WA, April 6–9, 2009. American Institute of Aeronautics and Astronautics (14 pp.).

Leshkevich, G.A., Nghiem, S.V., 2013. Great Lakes ice classification using satellite C-band SAR multi-polarization data. J. Great Lakes Res. 39 (S1), 55–64 (Special Issue on Remote Sensing, in this issue).

Leshkevich, G.A., 1985. Machine classification of freshwater ice types from Landsat-1 digital data using ice albedos as training sets. Remote Sens. Environ. 17 (3), 251–263.

Shuchman, R.A., Sayers, M.J., Fahnenstiel, G.L., Leshkevich, G., 2013. A model for determining satellite-derived primary productivity estimates for Lake Michigan. J. Great Lakes Res. 39 (S1), 46–54 (Special Issue on Remote Sensing, in this issue).

Wang, J., Haoguo, H., Schwab, D., Leshkevich, G., Beletsky, D., Hawley, N., Clites, A., 2010. Development of the Great Lakes Ice-circulation Model (GLIM): application to Lake Erie in 2003–2004. J. Great Lakes Res. 36, 425–436.