HICO Data User's Proposal

# Mapping inland lake water quality to support eco-epidemiological modeling of amyotrophic lateral sclerosis (ALS) risk factors

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Collaborators
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**Abstract**
Amyotrophic lateral sclerosis (ALS) is a progressive, fatal neurodegenerative disease and the etiology of sporadic ALS remains largely unknown. Water quality and the cyanobacteria toxin beta methyl-amino-alanine (BMAA) are suspected environmental triggers. Our overall goal is to develop an eco-epidemiological modeling approach to characterize the spatial relationships between ALS clusters and inland lake water quality risk factors derived from satellite remote sensing. The objective of this data proposal is to utilize HICO data to support water quality mapping. We will apply bio-optical and empirical data mining algorithms with in situ lake observations across a set of case studies during the summers of 2014 and 2015. All HICO results will be shared with HICO team members.

**Project Background**
Amyotrophic lateral sclerosis (ALS) is a progressive, fatal neurodegenerative disease with a lifetime risk of 1 in 400 (Wijesekera et al 2009). The pathologic hallmark of ALS is the selective death of motor neurons in the brain and spinal cord, producing debilitating symptoms of progressive weakness, muscle wasting and spasticity. The incidence of ALS is approximately 2 per 100,000 in the USA, amounting to 5,600 new cases diagnosed per year (Mitsumoto 1998). Mutations in genes underlying familial ALS (fALS) have been discovered in only 5-10% of the total population of ALS patients (Byrne et al 2011). Approximately 90% of ALS cases have no known genetic cause; this group is commonly called sporadic ALS (sALS) (Rosen 1993; Anderson 1997).

Despite many recent discoveries about the genetics of ALS, the etiology of sALS remains largely unknown. There is a broad scientific consensus that ALS is caused by gene-environment interactions. It is most likely that sporadic ALS results from a combination of underlying genetic susceptibility and environmental exposure to one or more toxins, but much remains to be discovered. The underlying genetic predisposing factors that render certain individuals more susceptible to a particular environmental toxin are also not well understood in ALS. The recently discovered hexanucleotide repeat expansion C9orf72 present in 7% of patients with sALS but only 0.2% of controls is likely to be one of those predisposing genetic factors (Majounie et al. 2012).

Evidence has shown potential linkages between water quality, cyanobacteria, and high ALS incidence (Bradley et al. 2013). Cyanobacteria are ubiquitous throughout all ecosystems and are particularly noxious when anthropogenic eutrophication of water-bodies causes large concentrations to form "blooms". It is well established that cyanobacteria produce a variety of toxins that have human health implications, including beta methyl-amino-alanine (BMAA) (Codd et al. 2005). The 50- to 100-fold higher incidence of ALS documented amongst the Chamorro people of Guam implicated the cyanobacterial neurotoxin BMAA found in components of their diet (Cox et al 2003).

The examination of other ecosystems has demonstrated the presence of BMAA in fish and crustaceans in the human food chain in Florida, Chesapeake Bay, Baltic Sea, France and Sweden (Field et al. 2013). BMAA has been demonstrated to be concentrated in the brains of ALS patients (but not controls) in Florida (Pablo et al. 2009) and to be mis-incorporated into neuronal proteins via the L-serine tRNA-synthetase system (Dunlop and Rodgers 2011). Clusters of ALS have been reported near cyanobacterial bloom outbreaks in France, Japan, New Hampshire, and Wisconsin (Caller et al 2012). Caller et al. (2009) shows a statistically significant 2.3-fold increased incidence of ALS in subjects residing within 0.5 miles of a New Hampshire lake that experienced cyanobacteria blooms. Potential routes of exposure include aerosolization, dermal contact, ingestion of water, and dietary exposure through the aquatic food web. Torbick et al (2014) found that poorer water quality conditions that promote cyanobacteria were significantly associated with increased odds of belonging to an ALS cluster in northern New England.

- The **objective** of this data proposal is to support mapping of inland lake water quality parameters and help drive an eco-epidemiological model investigating linkages between lake water quality and ALS.

**HICO data request**

- HICO data (L1B/L2A) will be used to generate lake water quality metrics / maps
- Optimally, we can work closely with HICO team to coordinate ISS HICO collection during the summers (August/September) of 2014 & 2015 to obtain near simultaneous in situ collection systematically across case study sites
- We will test / developed algorithms (bio-optical and empirical) and share all outcomes
- HICO data will be fused with observations from Landsat 8 OLI, MODIS, and high resolution commercial imagery (Digital Globe World View)

**Coordinates and target dates**

| Study Area | Target Dates | UL | LR | in situ center point | Width (km) | Length (km) | Approximate Area (km) |
|---|---|---|---|---|---|---|---|
| Lake Champlain | Aug 7, 23, Sep 8, Sep 24 | 45N, 73.5W | 44N, 73W | 44.2N x 73.2W | ~30 | ~100 | 3000 |
| NH Lakes Region | Aug 9, 25, Sep 10, 26 | 43.9N, 71.7W | 43.25N, 70.75W | 43.6N x 71.25W | ~50 | ~40 | 2000 |

**Study Areas**

ALS databases have been built across geographically diverse regions that cover a range of lake states. Within each region we plan to collect a suite of lake parameters and scaled imagery.

- Study Area #1.) Lake Champlain (VT/NY)
- Study Area #2.) Central and southern New Hampshire

Lake in situ data: At strategic lakes we plan to work with key local government agencies as well as collect water samples ourselves. We will focus on collecting Secchi Depth, Dissolved Oxygen, Chl, Total Suspended Solids, Total Nitrogen, Total Phosphorus, Non-Purgable Organic Carbon (NPOC), and identify major phytoplankton types (PFT) and key concentrations (e.g., microcystins, phycocyanin). We will utilize a suite of instruments (ASD Field Spec Pro, WET labs autonomous buoy, YSI XO-1, LI-250, etc…) and ELISA kits following established procedures. Integrated tube samples of the epilimnion will be taken for collection of phytoplankton, zooplankton, extracted chlorophyll a, nutrients, and cyanotoxins. Water variables will be collected in lab bottles at each site and filtered through a 47mm Whatman GF/F filter

(0.7 membrane); chl samples will be supplemented with 9mL 90% ETOH and sonicated for 15 minutes; filters will be removed and ETOH solutions centrifuged for 10 minutes; fluorometers will measure response values (Rc) to eventually equate to Chl-a. TSS levels will use the TSS/ISS filter method. Samples will be weighed, dried, and transferred to a desiccator and weighed and then loss on ignition calculated to obtain lake level TSS. NPOC will be determined using Shimadzu TOC-Vcph carbon analyzer with the total nitrogen module (TNM-1) and ASI-V automsampler. Phytoplankton community counts will follow the Soft Algae Count technique. Species composition, size, number of colonies, and biomass will be determined under microscope at 1mL intervals using a Palmer-Maloney counting chamber.

## Nathan Torbick- Biographical Sketch

A. PROFESSIONAL PREPARATION

| College/University | Major | Degree &Year |
|---|---|---|
| University of New Hampshire | Natural Resources | BS, 2001 |
| Ecoquest – New Zealand | Natural Resources | 2003 |
| University of Toledo | Geography | MS, 2004 |
| Int. Livestock Research Inst. | Biological Systems | 2006-2007 |
| Michigan State University | Geography | PhD, 2007 |

B. ACADEMIC/PROFESSIONAL APPOINTMENTS

| | |
|---|---|
| 2013 – present | Director, Human & Environment Interactions Analysis, Applied Geosolutions |
| 2010 – 2013 | Senior Research Scientist, Applied Geosolutions, Durham, New Hampshire |
| 2006 – 2010 | Research Scientist, Applied Geosolutions, Durham, New Hampshire |
| 2004 – 2007 | Graduate Research Scientist, Center for Global Change & Earth Observation, Dept. of Geography, Michigan State University |
| 2002 – 2004 | Graduate Research Assistant, Geographic Science Lab, University of Toledo |
| 1997 – 2002 | Research Assistant, Climate Change Research Center, University of New Hampshire |

C. PUBLICATIONS

Publications Most Closely Related to Proposal (5)


Torbick, N, Hession S, Stommel E, Caller T. 2014. Mapping amyotrophic lateral sclerosis lake risk factors across northern New England. International Journal of Health Geographics, 13:1.

Torbick N, Hession S, Hagen S, Wiangwang N, Becker B, Qi J. 2013. Mapping inland lake water quality across the Lower Peninsula of Michigan using Landsat TM imagery. International Journal of Remote Sensing 34:7607-7624.

Torbick, N. Becker, B., Hession, S., Qi, J. Roloff, G., Stevenson, J. 2010. Assessing invasive plant infestation and disturbance gradients in a freshwater wetland using a GIScience approach. Wetlands, Ecology, and Management. DOI: 10.1007/s11273-009-9171-5

Torbick, N. Feng Hu, Jianying Zhang, Jiaguo Qi, Hangjun Zhang, and Brian Becker. (2008). Mapping Chlorophyll-a Concentrations in West Lake China using Landsat 7 ETM+. Journal of Great Lakes Research, 34, 3.

Torbick, N., J. Qi, R. Roloff, and R. J. Stevenson, 2006. Investigating impacts of land use land cover change on wetlands in the Muskegon River Watershed, Michigan, USA. Wetlands, 26, 1112-1123.

D. SYNERGISTIC ACTIVITIES

- Active on NASA Land Cover Land Use Change (LCLUC), NASA Terrestrial Ecology (TE), USDA, and NIH SBIR projects developing datasets for science community and decision makers; assessing impacts of land use land cover changes on water, climate, and environmental outcomes, and human – environment interactions
- Leader in developing products for CDC Environmental Public Health Tracking (EPHT) program
- Active in the ALOS PALSAR Kyoto & Carbon Initiative (K&CI) develop science and products
- Reviewer for several remote sensing, geography, water resources, and modeling journals
- Board of Director for New Hampshire Coastal Protection Partnership (NH Coast)

COLLABORATORS AND OTHER AFFILIATIONS

Becker, B. (Central Michigan University), Biradar, C. (Oklahoma University), Caller, T. (DHMC), Czajkowski, K. (University of Toledo), Ducey, M. (University of New Hampshire), English, P. (California EHPT), Fan, P. (Michigan State University), Ge, J. (Oklahoma State University), Hagen, S. (AGS), Ingraham, P. (AGS), Kalkstein, L. (University of Miami), Krause, A. (University of Toledo), Lawrence, P. (University of Toledo), Li, C. (University of New Hampshire), McLellan, E. (Environmental Defense Fund), Moore, N. (Zhejiang University/MSU), Moore, T. (University of New Hampshire) Palace, M. (University of New Hampshire), Qi, J.(Michigan State University), Salas, W. (AGS), Siqueira, P. (U. Mass), Stommel (DHMC), Tomer, M. (USDA ARS), Varner, R. (University of New Hampshire), Xiao, X. (Oklahoma University)

Graduate Advisors

Jiaguo Qi, David Lusch, Jan Stevenson, Gary Roloff (Michigan State University); Ph.D.
Kevin Czajkowski, Patrick Lawrence (University of Toledo); M.S.

**Applied Geosolutions Facilities**

AGS has two offices with approximately 7500 square feet. AGS computing infrastructure includes multiple Linux workstations, PC workstations, and windows-based PCs. AGS utilizes a mixed environment gigabit network consisting primarily of Ubuntu Linux servers and several Ubuntu, Windows and OSX desktops. All servers run in a virtualized environment utilizing VMWare (Hypervisor 5) running on Dell rack PowerEdge servers. With shared storage across multiple servers, this ensures that virtualized instances of key servers can be brought up with minimal amount of downtime, while battery backups allow on servers allow for up to 30 minutes of power loss. Data is all stored on RAID-10 or RAID-5 storage arrays, using either hardware (Dell PowerVault) or Linux software raids. Nightly mirroring to a RAID 5 disk is performed on critical data and configuration files to allow for fast and speedy recovery in the case of primary disk failure. Disaster recovery is in place with periodic off site backup with all data behind multiple firewalls to prevent intrusion. Production web and data servers are also separated from internal networks following best practices. AGS software includes GIS, database and image processing licensed software, including ArcGIS, ENVI, IDL, MySQL, ACCESS, etc, as well as open source software for mobile and web-GIS production (Postgres/POST GIS, University of Minnesota Mapserver, etc). Sophisticated security meeting NIH, NASA, and NSF requirements is in place as well as firewalls and virus protection. No sensitive information is stored on the network.

**Output & Deliverables**

- Assessment of HICO data performance and utility for mapping diverse inland waters
- Maps of inland lake water quality (chl-a, PC, TSI, TN) derived from HICO data served open source
    - Geotiff format following standard (GEOSS/ISO-19115) for meta data content and structure
- Algorithms applied to data, summary statistics, & report (csv, doc, pdf, ppt)

- Contribution science addressing water quality and human health
    - Specifically cyanobacteria and ALS
- Support Missions / Programs at NSF, NASA, and NIH
    - Current and Pending sources for this work

**References**

Bradley WG, Borenstein AR, Nelson LM, Codd GA, Rosen BH, Stommel EW, Cox PA. 2013. Is exposure to cyanobacteria an environmental risk factor for amyotrophic lateral sclerosis and other neurodegenerative diseases? Amyotroph Lateral Scler Frontotemporal Degener PMID:23286757.

Byrne S, Walsh C, Lynch C, Bede P, Elamin M, Kenna K, McLaughlin R, Hardiman O. 2011. Rate of familial ALS: a systematic review and meta-analysis. J Neurol Neurosurg Psychiat 82:623-627

Caller TA, Doolin JW, Haney JF, Murby AJ, West KG, Farrar HE, Ball A, Harris BT, Stommel EW. 2009. A cluster of amyotrophic lateral sclerosis in New Hampshire: A possible role for toxic cyanobacteria blooms. Amyotroph Lateral Scler 10:101-108.

Caller TA, Field NC, Chipman JW, Shi X, Harris BT, Stommel EW. 2012. Spatial clustering of amyotrophic lateral sclerosis and the potential role of BMAA. Amyotroph Lateral Scler 13:25-32

Codd GA, Morrison LF, Metcalf JS. 2005. Cyanobacterial toxins: risk management for health protection. Toxicology and Applied Pharmacology 203:264-272.

Cox PA, Banack SA, Murch SJ. 2003. Biomagnification of cyanobacterial neurotoxins and neurodegenerative disease among the Chamorro people of Guam. Proc Nat Acad Sci 100:13380-13383

Dunlop R, Rodgers K. 2011. Proteins containing BMAA form autofluorescent aggregates and induce cell death. Amyotroph Lateral Sclero 12:156.

Field N, Metcalf J, Caller T, Banack S, Cox P, Stommel E. 2013. Linking beta-methylamino-l-alanine exposure to sporadic amyotrophic lateral sclerosis in Annapolis, MD. Toxicon 70:179-183.

Majounie E, Renton AE, Mok K, Dopper EG, Waite A, Rollinson S, et al. 2012. Frequency of the C9orf72 hexanucleotide repeat expansion in patients with amyotrophic lateral sclerosis and frontotemporal dementia: a cross-sectional study. Lancet Neurol 11:323-330.

Mitsumoto H, Chad DA, Pioro EP. 1998. Amyotrophic Lateral Sclerosis. Philadelphia, PA. F.A. Davis Company

Torbick, N. Hession, S., Stommel, E. Caller, T. 2014. Mapping amyotrophic lateral sclerosis lake risk factors across northern New England. International Journal of Health Geographics 2014, 13:1.

Wijesekera, L. Leigh, P. 2009. Amyotrophic lateral sclerosis. Orphanet Journal of Rare Diseases 2009, 4:3.

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