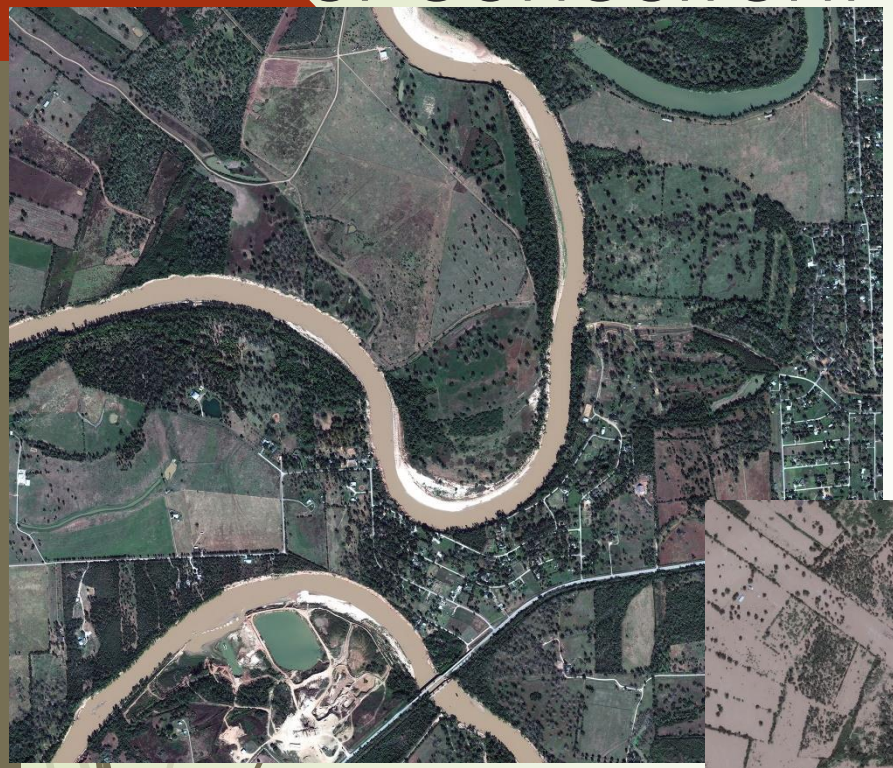
Capturing and analyzing geographic information of high spatial and temporal resolutions to solve the on-going problems

- Dr. Tao Tang
- Professor of GIS, Remote Sensing and Geography
- Department of Geography and Planning
- SUNY – Buffalo State College
- Email: tangt@buffalostate.edu
- Phone:716-878-4138

For a long time, one of the major focuses of GIS practitioners is the spatial data and spatial analysis

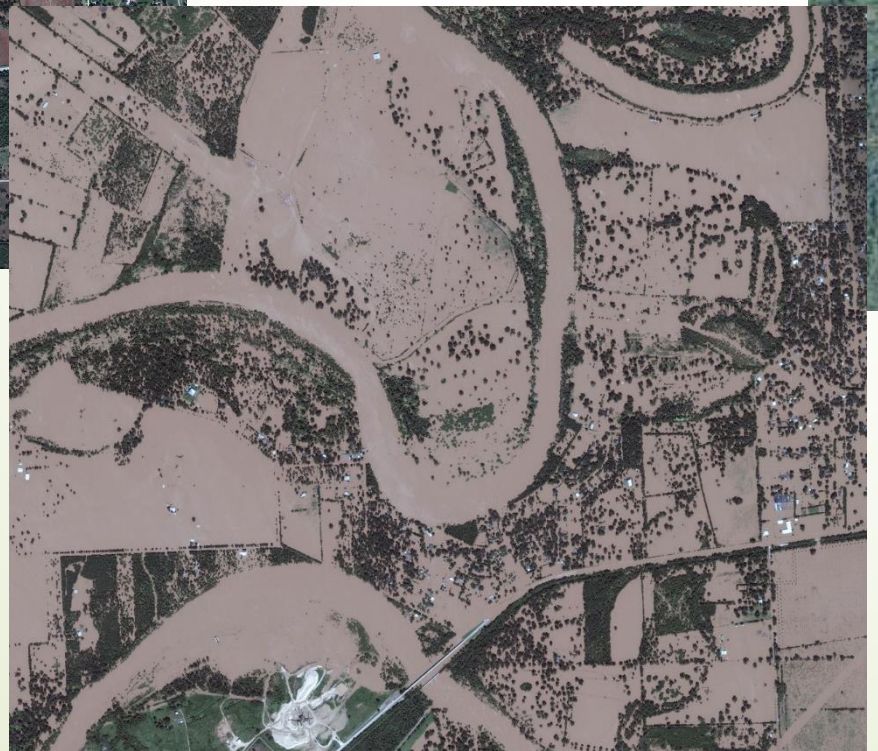
- Spatial datasets carry temporal or time information and characteristics as well.
- GIS practitioners must also answer questions as "what is happening?" or "what just happened?" in many problem solving projects.

Capturing, analyzing, and visualizing time sensitive or concurrent spatial data are very important



- Hurricane Harvey Flooding – Huston, TX
- Left: November, 2016
- Bottom: August 30, 2017

Earthquake, China Before and After



Time is the fourth dimension in GIS

- Changes of geographic features or their distributions are relatively slow

- From left to right

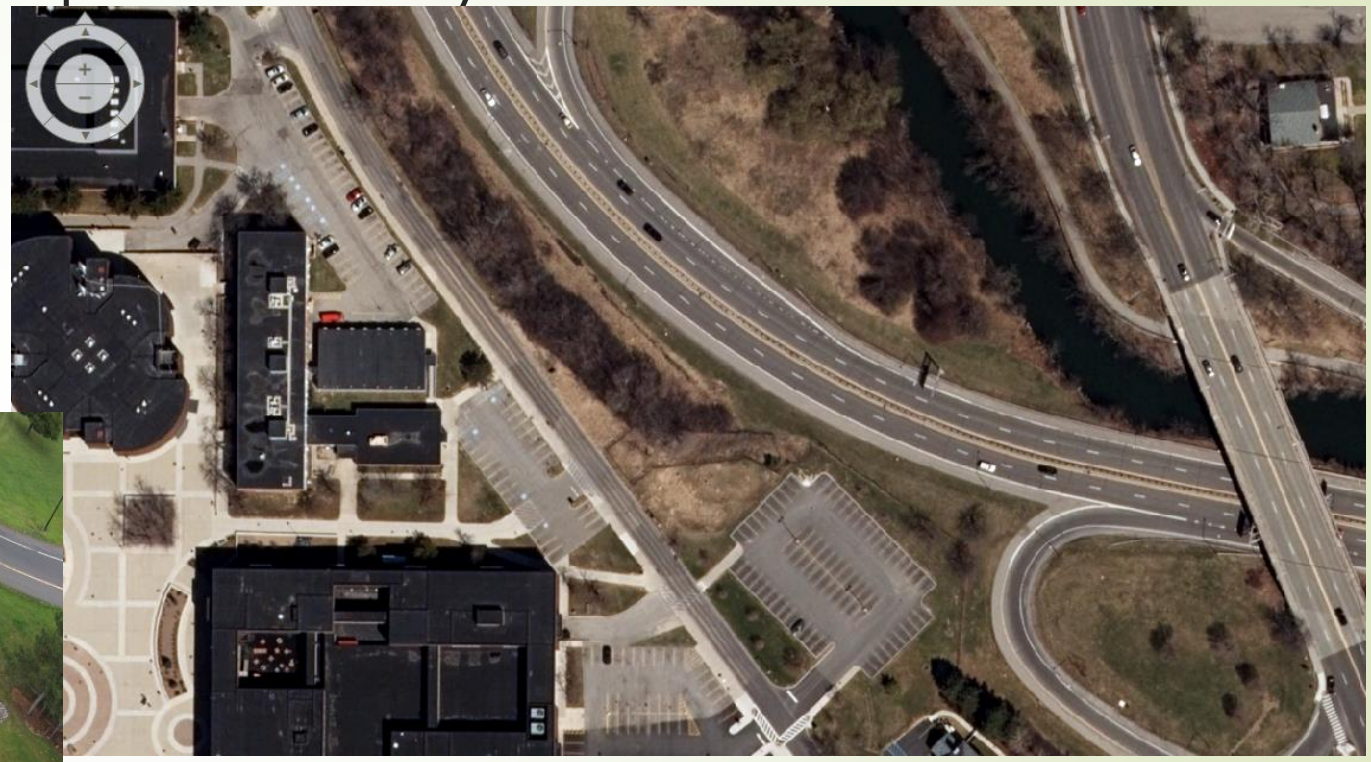
Fast changes – Earthquake, Japan

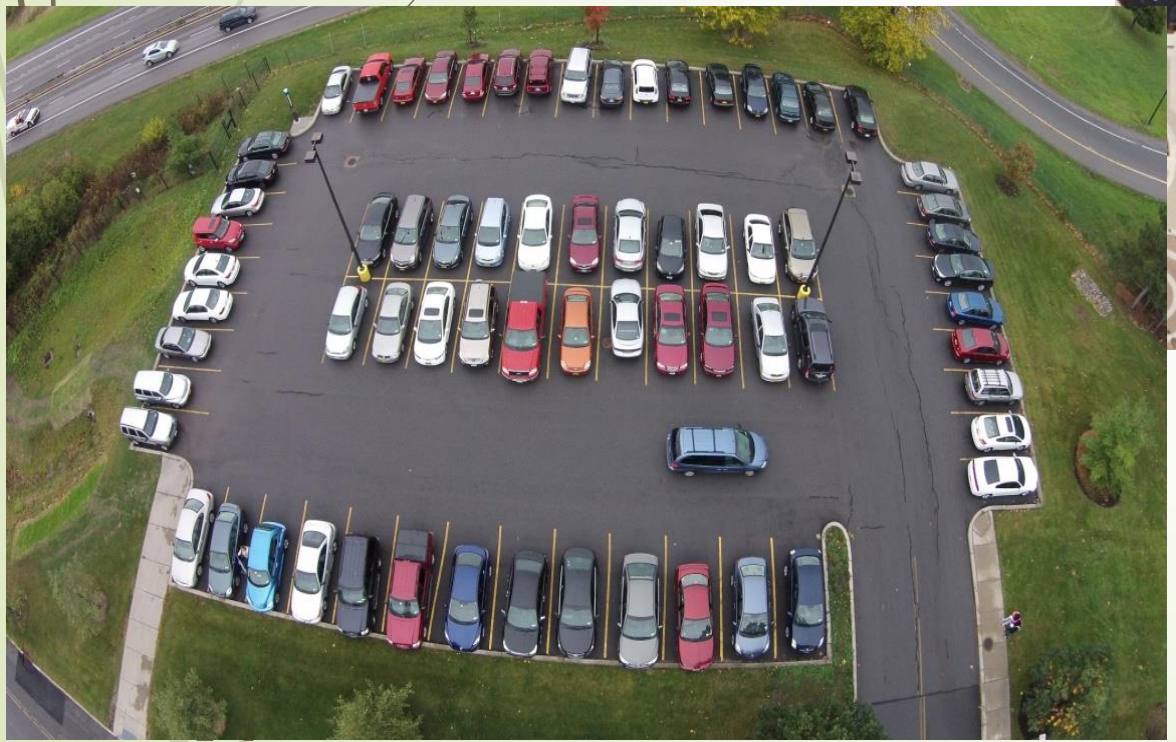
Large map scale or high spatial resolution does not mean the time scale is accurate or it is concurrent time for conducting specific geographic or spatial analysis.

- NY State digital orthographic aerial photographs of 2014

– one foot spatial resolution

- Low temporal resolution - "Historical"





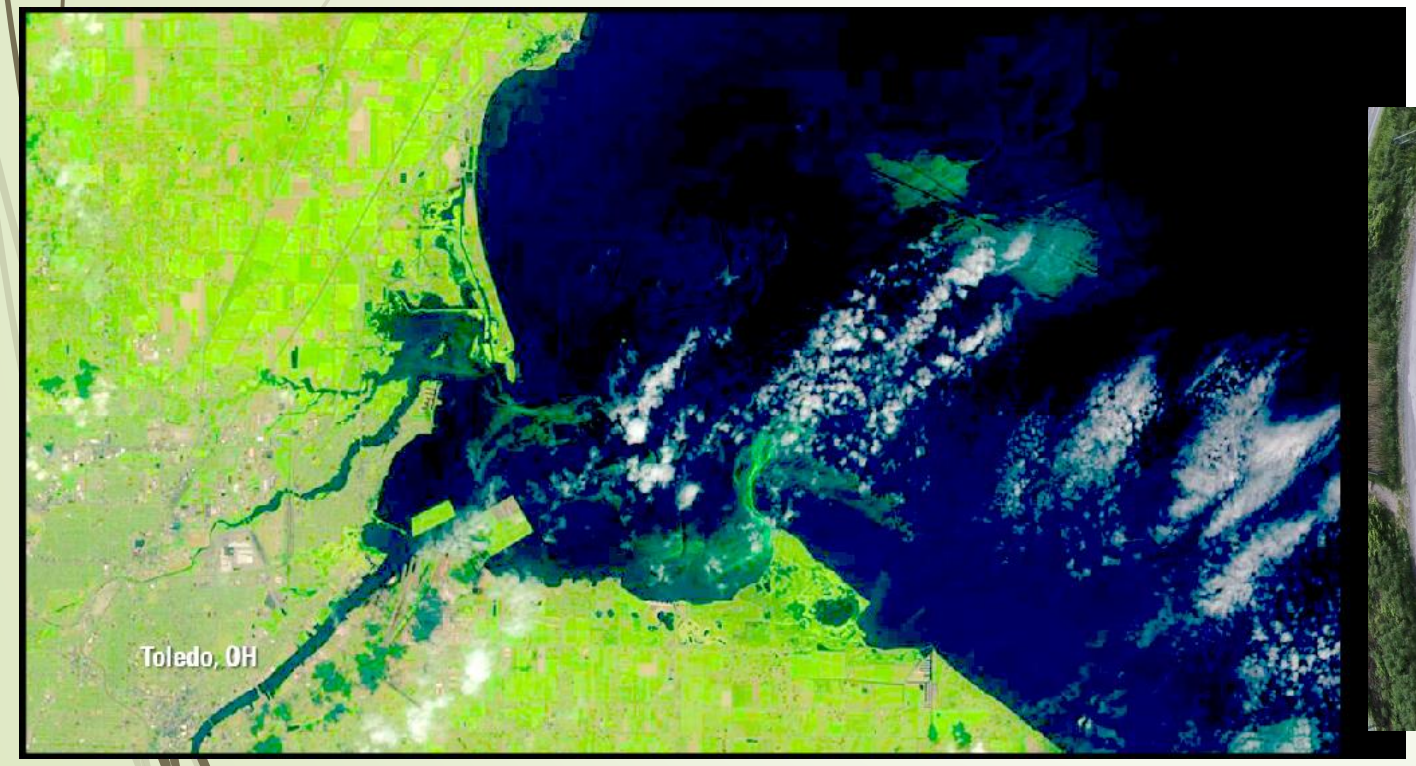
Drone (UAV) data – "What is happening now?"

High temporal resolution

The concepts of time dimension and time scale need to be implemented in GIS studies

- 1. Time-interval: periods of time located on the temporal continuum (or time-plenum) that serve as the base or units of the temporal theory
- 2. Time-duration: certain amount of time that can be compared and are distinctive from the length of the time interval are used to define the existence – geographic features or events.
- 3. Time-point: a position in temporal coordinate system which has no duration and is useful in locating event on the time-plenum.
- (Hynes, 1994; Gruber et al., 1994; Tegtmeier, 2009; Petnga and Austin, 2013)

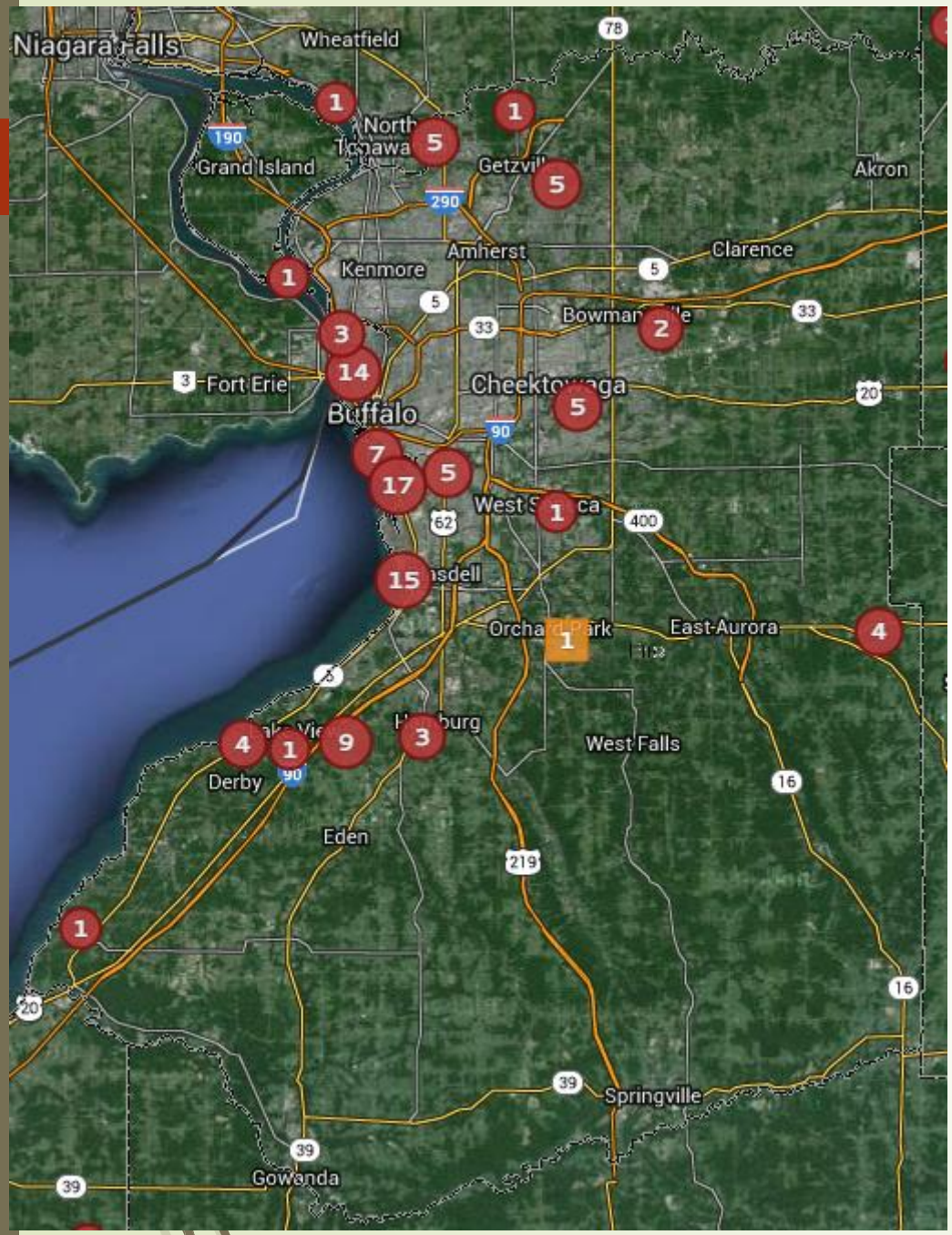
Different than spatial scale, time scale refers the size of temporal intervals either built subjectively or objectively for measuring or testing theory of a geographic process or existence of geographic patterns, or geographic features and events.



- Algae bloom in the Lake Erie, August 1, 2014

Patches of Japanese Knotweed invasive species – June, 2016

Time sensitive GIS experiment project #1:
Spatial analysis of distributions and habitat conditions of Fallopia japonica (Japanese Knotweed) invasive species applying drone (UAV)remote sensing – with Ms. Jiazhen Zhang

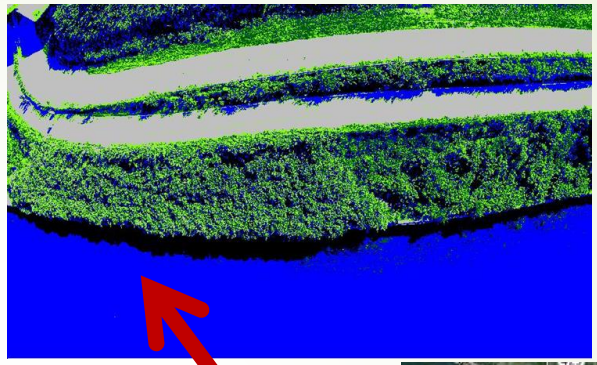


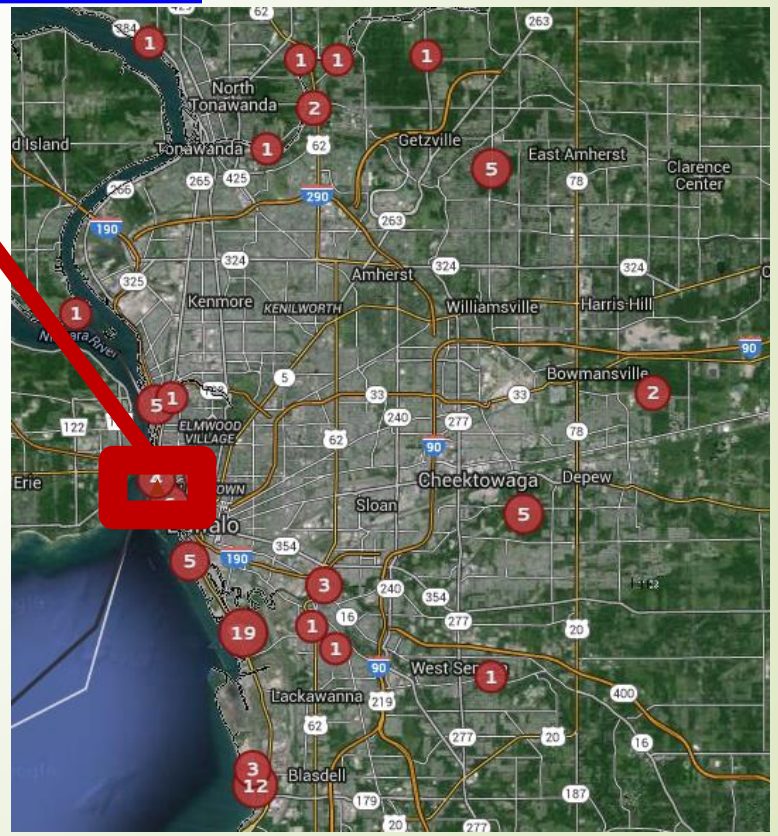
iMap Invasive website

- Japanese knotweed is a herbaceous perennial plant species native to East Asia in China and Japan.
- It is one of the world's worst invasive species, as World Conservation Union (WCU) listed.
- New York State Department of Environmental Conservation (NYS-DEC), in collaboration with the Cornell University, established the iMap Invasive website for crowdsourcing the reports of invasive species by the people doing recreation activities.
- However, the iMap Invasive internet based sensor system and its database do not record the time, intensity, and distribution of invasions.
- iMap Invasive does not verify the growing situation and current distributions of invasive species.

The objectives of this study are:

- 1. To locate and verify the major distributions of the F. japonica (Japanese knotweed) in Erie County, New York (2016 summer)
- 2. To measure the invasion area of F. japonica (Japanese knotweed)
- 3. To analyze the habitat conditions of the F. japonica (Japanese knotweed) invasive species in a three dimensional (3 D) environment.



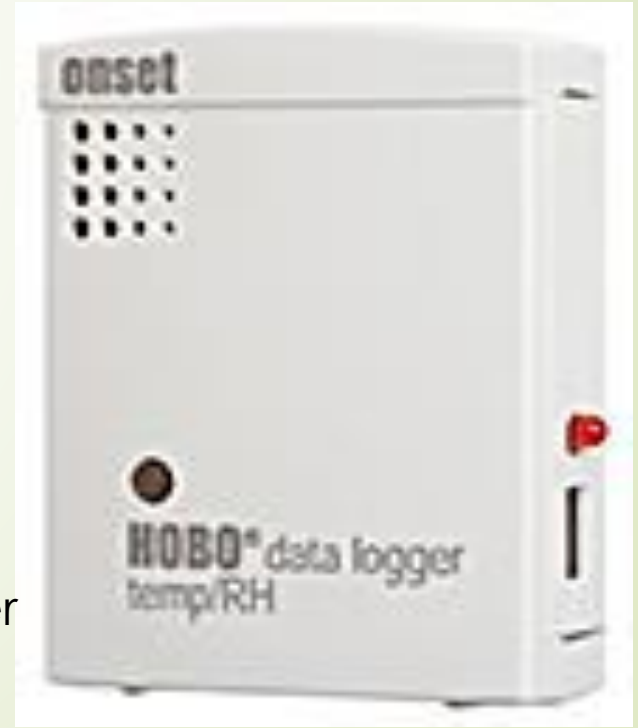


Methods

- Aerial images, temperature data, and relative humidity (RH) data were collected in-situ using an unmanned helicopter (UAV) and the on-board sensors.
- HOBO meteorological data logger/sensor was utilized to collect temperature and relative humidity (RH) data.
- The images and attribute data of the micro-climate were collected with both time and location stamps.

Original aerial image

Data logger



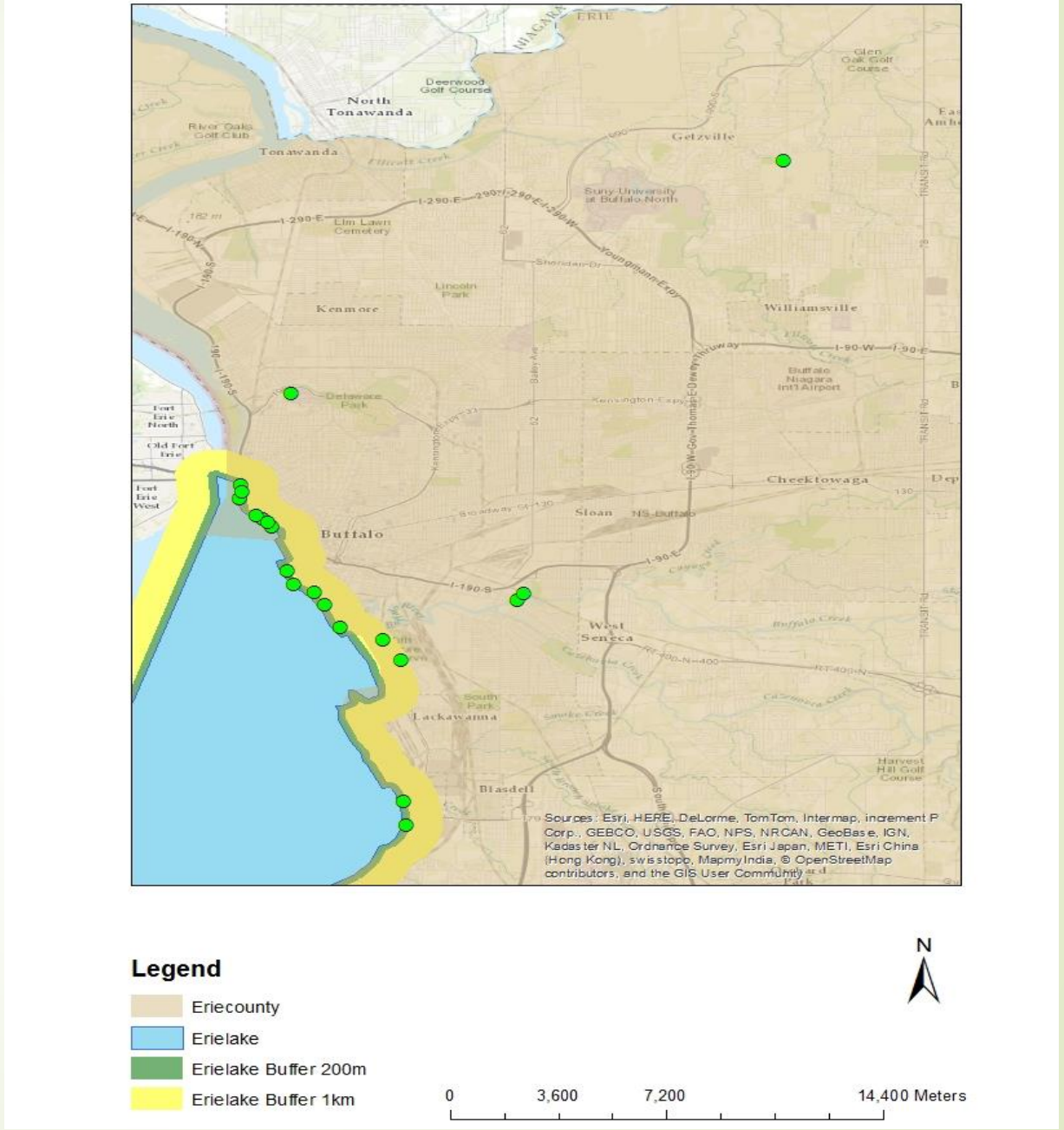

onset
HOBO data logger
temp/RH

Results and Discussions

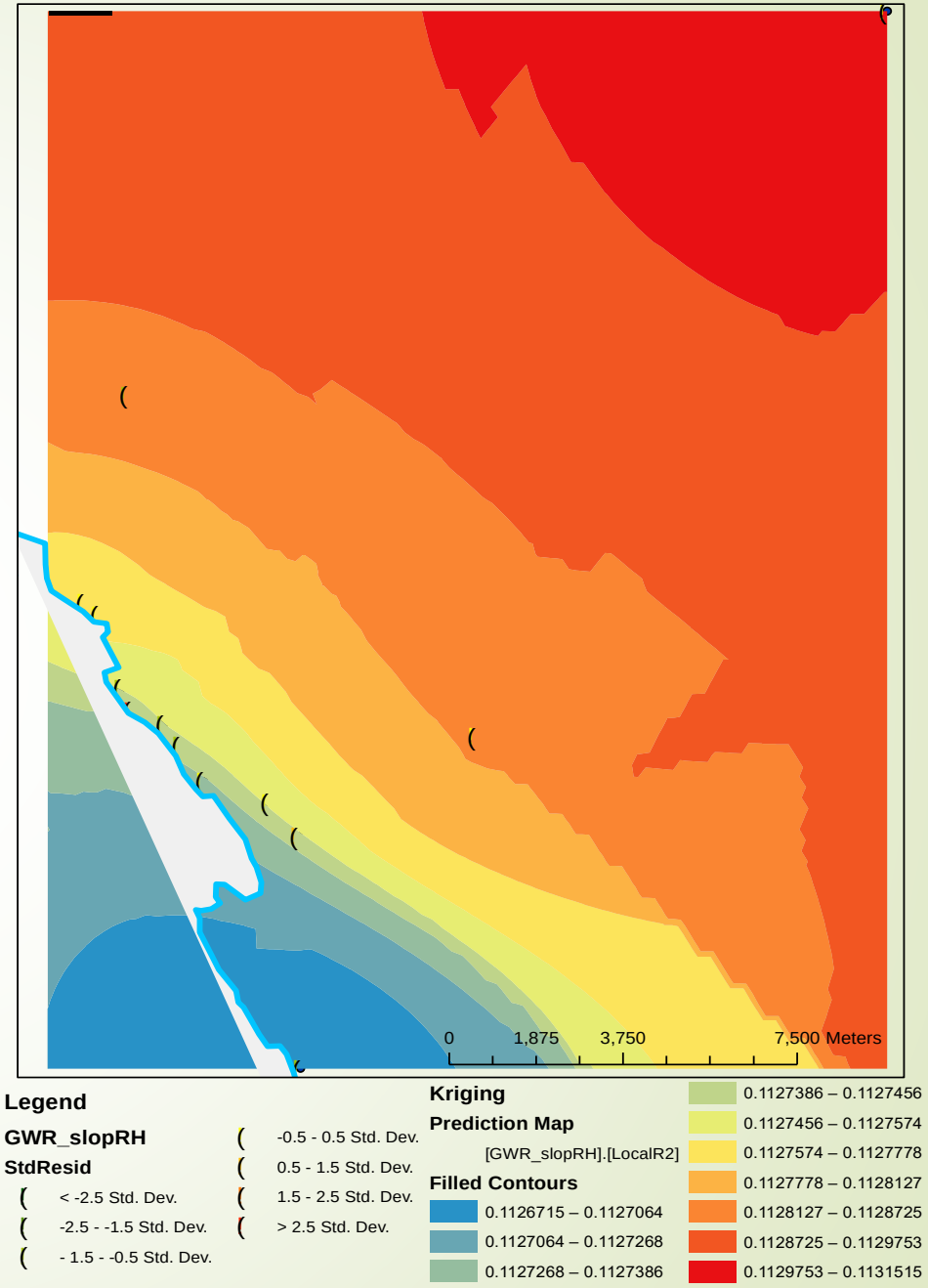
- Example of Summary table of Japanese Knotweed verification and invasive areas

ID(website)	Latitude (°)	Longitude (°)	Observed date	watershed	Appearances in field investigation	Area (m^2)
NY-321254U	43.05298	-78.77005	May 14, 2014	Tonawanda Creek	No	NA
NY-330332U	43.01586	-78.73879	Aug. 13, 2014	Tonawanda Creek	Yes	61.864
NY-330153U	43.01561	-78.73810	Aug. 13, 2014	Tonawanda Creek		
NY-330146U	43.01495	-78.73812	Aug. 13, 2014	Tonawanda Creek		
NY-328010U	42.89240	-78.71712	June 10, 2014	Buffalo River	Yes, burgeon	NA
NY-313476U	42.88907	-78.72793	May 11, 2011	Buffalo River	No	NA
NY-321629U	42.93154	-78.89361	June 4, 2014	Tonawanda Creek	Yes	124.63
NY-321534U	42.90403	-78.90150	May 29, 2014	Buffalo River	Yes	2505.8
NY-321549U	42.90268	-78.90146	May 29, 2014	Buffalo River	Yes	4076.57
NY-321565U	42.90066	-78.90068	May 29, 2014	Buffalo River	Yes	134.11
NA	42.90048	-78.90094	NA	Buffalo River	Yes	148.37
NY-319838U	42.88866	-78.88994	Aug. 9, 2013	Buffalo River	Yes	482.69
NY-319835U	42.89082	-78.89089	Aug. 9, 2013	Buffalo River	Yes	95.766

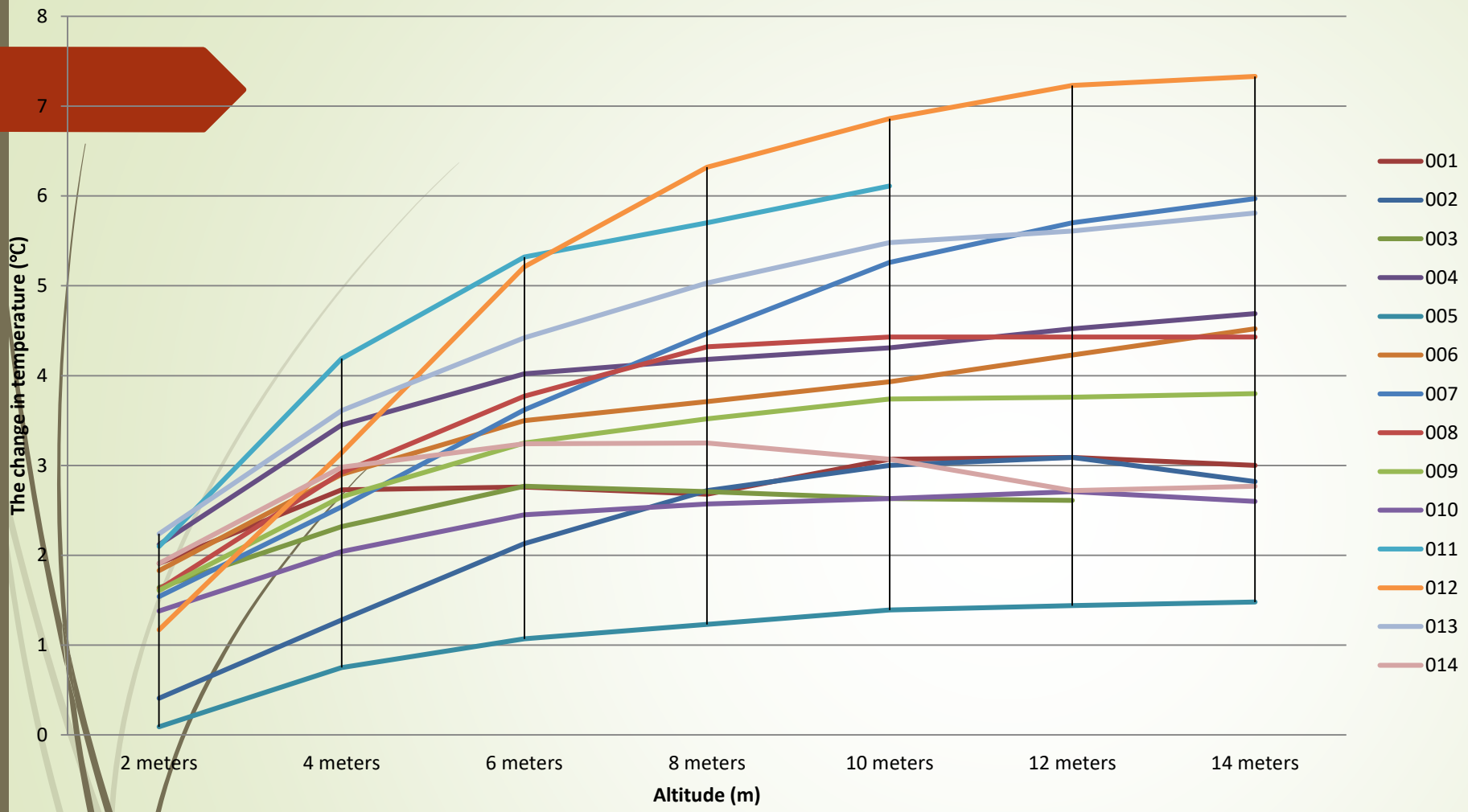
- Most of the Japanese Knotweed invasive plants are located in the 200-meter buffer area around the Lake Erie.
- Only four out of 20 detected sites of invasion were located outside the 1,000-meter buffer area.



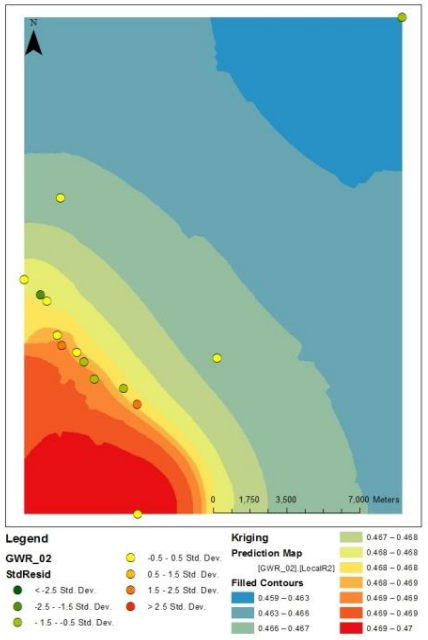
- Since the measured temperature and relative humidity (RH) at different sampling days vary, the temperatures and RH at different altitudes were subtracted from ground surface temperatures and RHs at the same time to normalize the values in the measured datasets.
- Relative humidity (RH) shows no clear spatial patterns as the altitude increases from ground level to 14 meters above the ground. However, it does show the horizontal changes from the Lake Erie shore to the inland areas (following figure).



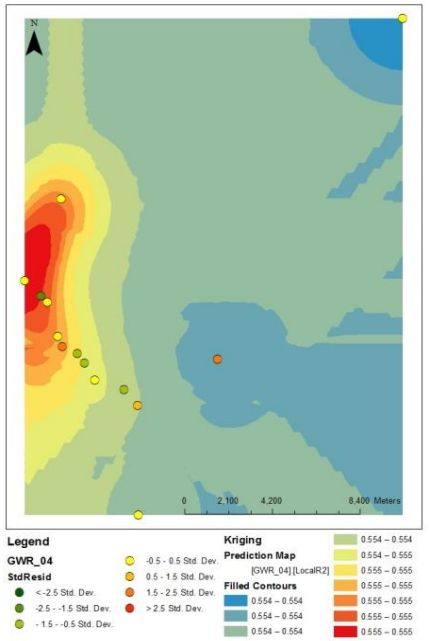
The change in temperature of each of *F.japonica* patches



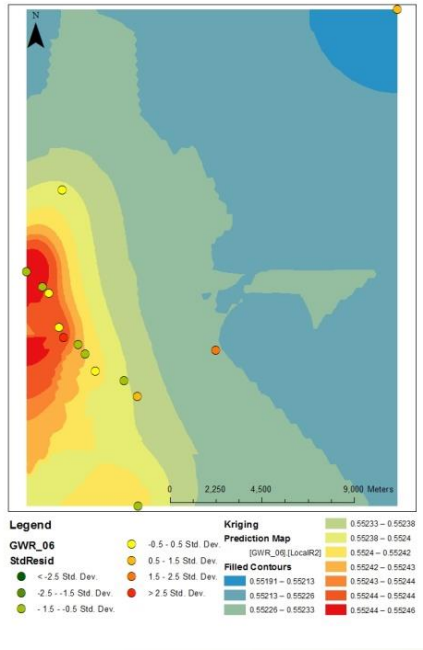
- The temperature shows decrease as the altitude increases within 14 meters from the ground. However, it does not follow the normal lapse rate (0.64 °C per 100 meters)



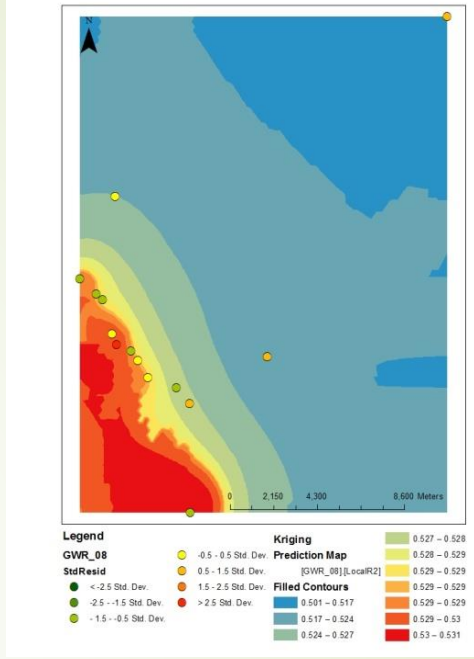
A.



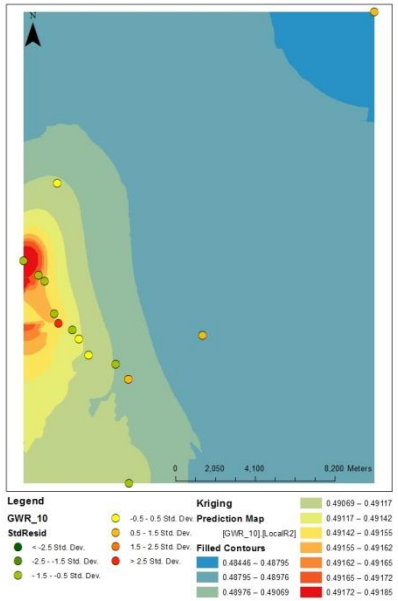
B.



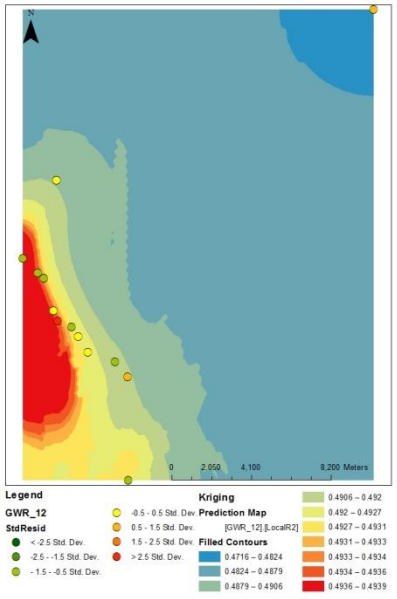
C.



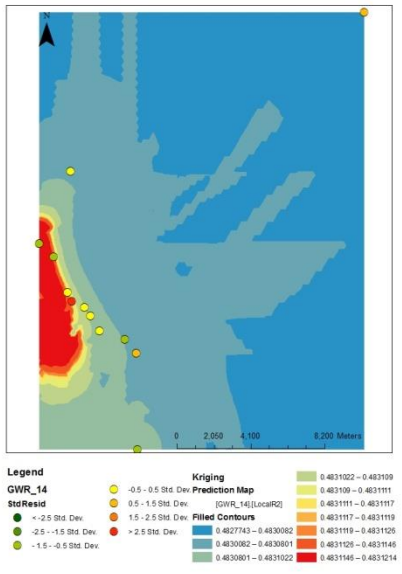
D.



E.



F.



G.

- Temperature distribution at different altitudes:

a) 2m; b) 4m; c) 6m; d) 8m; e) 10m; f) 12m; g) 14m.

Time sensitive GIS experiment project #2:
Habitat Condition Analyses of Water Chestnut (Trapa natans) Invasive Species along the Lower Tonawanda Creek Applying Drone (UAV) Remote Sensing

- with Ms. Lily Jiang, Dr. Chris Pennuto, Ms. Mary Perrelli

- DJI – Inspire drone with capability of payload senor exchange

The objective of this project is to develop a transferrable protocol to use low-altitude unmanned vehicle technology to perform rapid detection and coverage estimation of invasive species.

- The field study and investigations were performed along the lower Tonawanda Creek and the Erie Canal system from its western terminus east to the confluence of the canal and the creek.

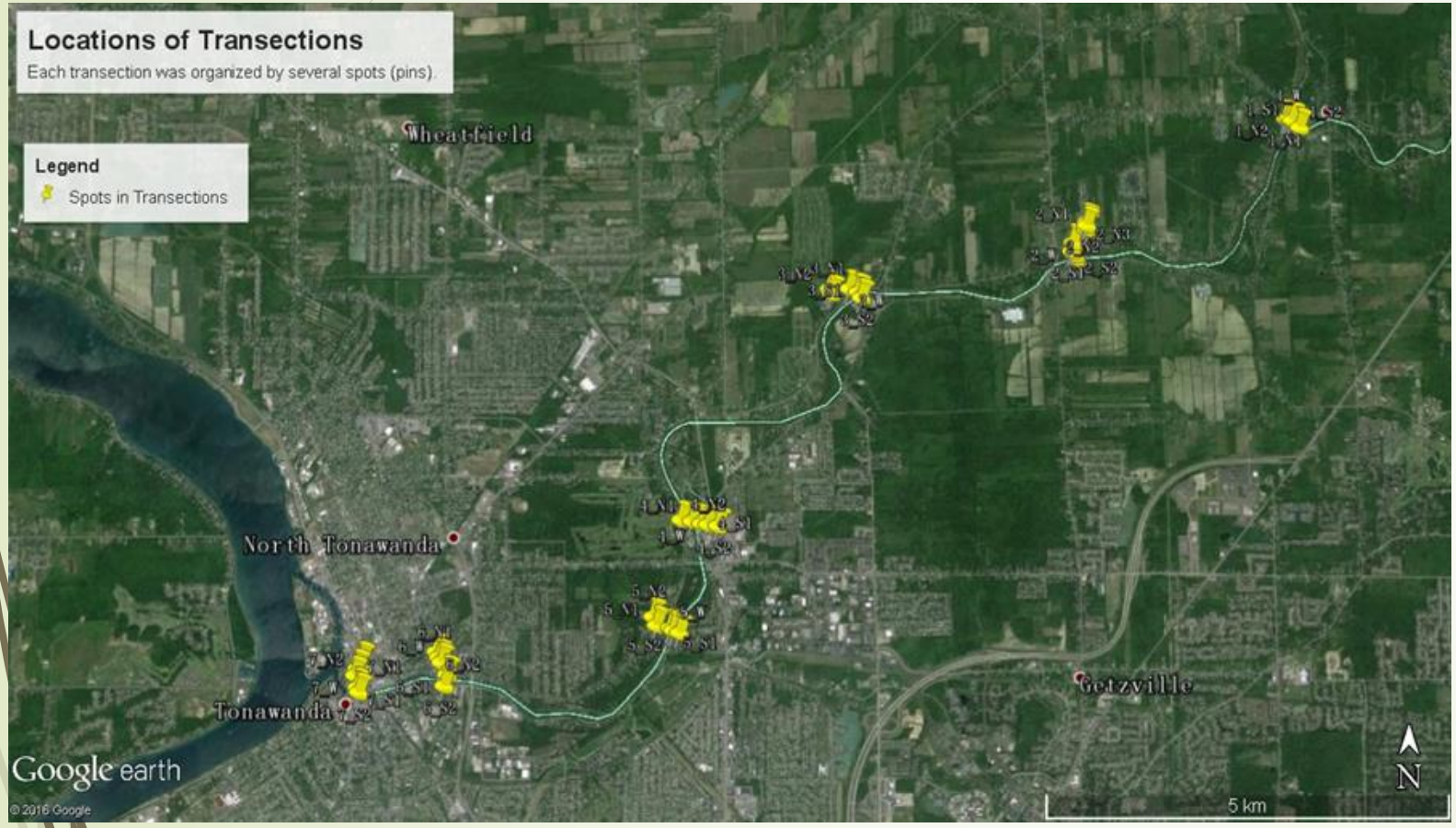
- Scientists at the Lower Great Lakes Fish and Wildlife Conservation Office, U.S. Fish and Wildlife Service (USFWS) have been working for seven years (2010 – 2016) to physically remove the water chestnut invasive species in this area.

- This project also serves as the repaid reconnaissance of current existence of the invasive species.

Both DJI Phantom 3 professional and Inspire 1 Pro drones were used to conduct field data collections

- One equipment was lost in the bottom of the river at the Tonawanda Creek during the field data collections.

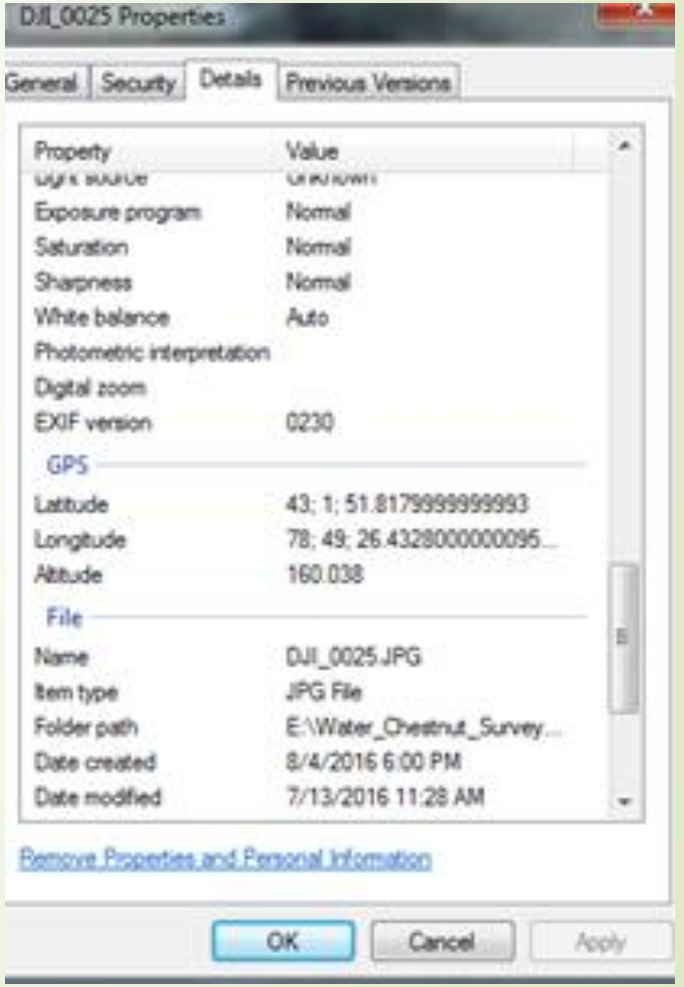
The micro-climatic habitat conditions were also sampled using a payload senor (HOBO data logger)through the cross-sections along the creek.



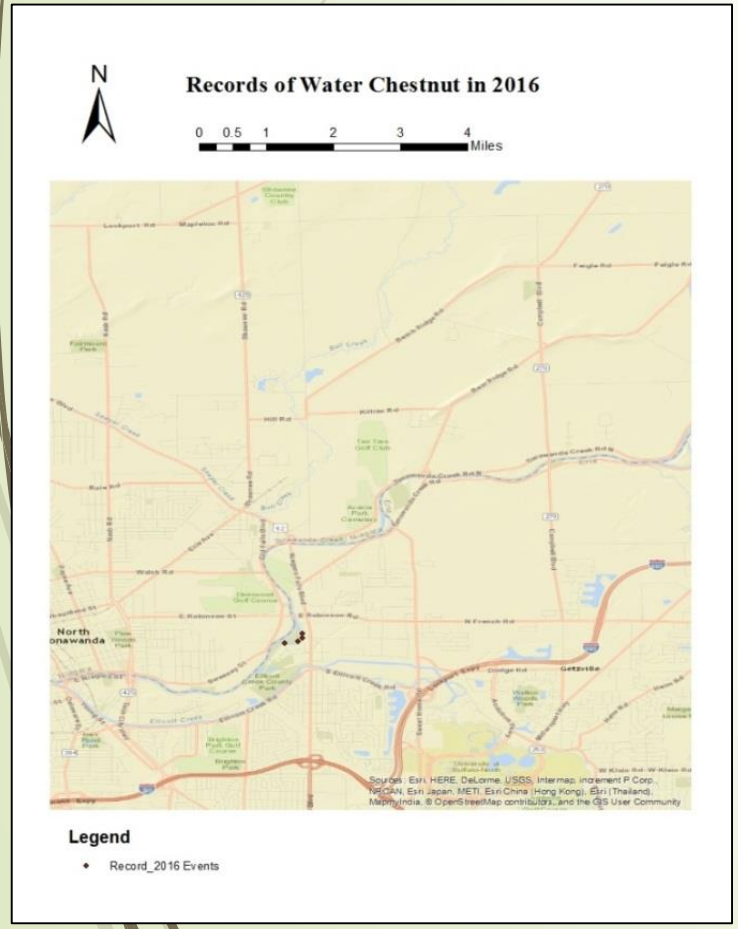
HOBO Data Logger

- The Locations of the Field Transects

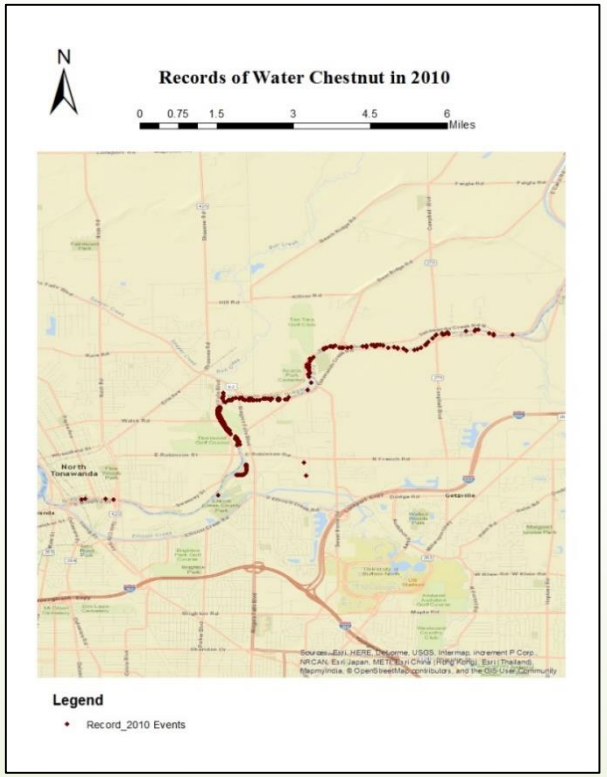
Example- Close Range Aerial Photograph of Water Chestnut Patch and Drone Recorded GPS Locational Information

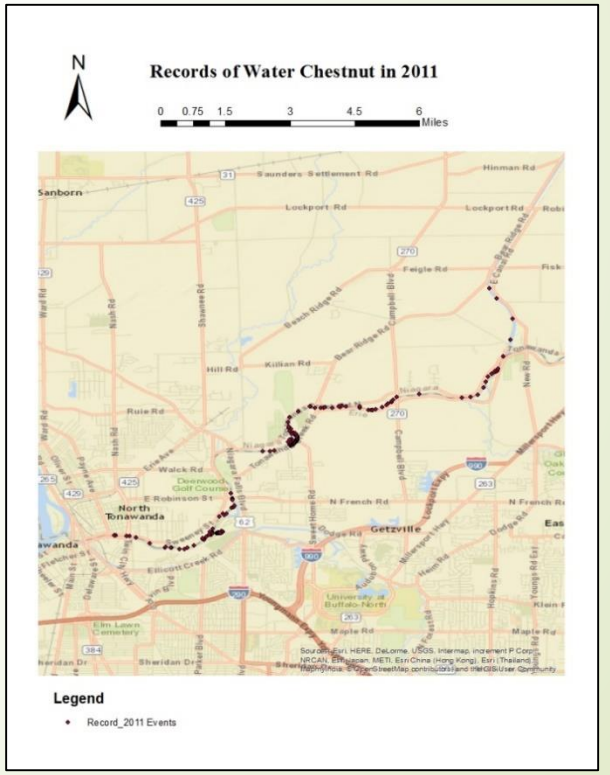


In comparison of drone survey in 2016 with boat based survey by US -FWS previously, the time sensitive results show the effectiveness of physical removal over years.

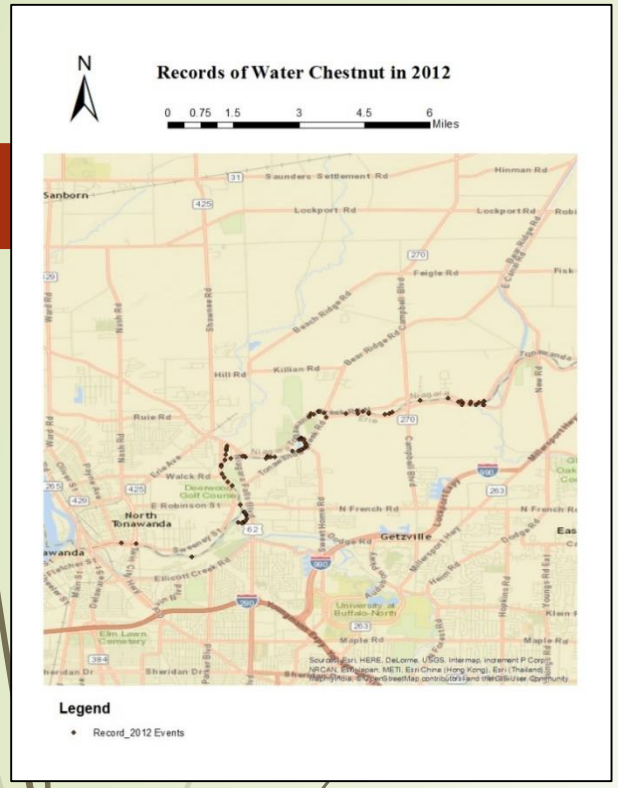


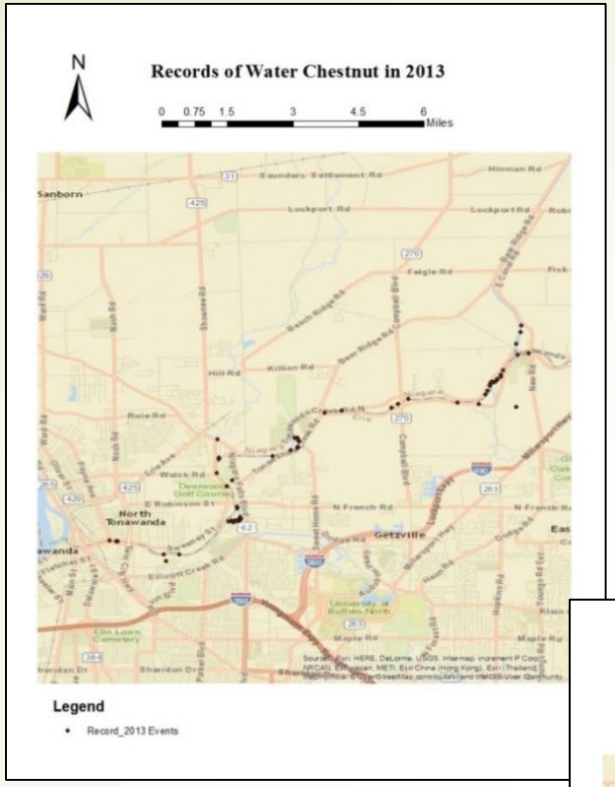
- Records of Water Chestnut observations by AUV in 2016





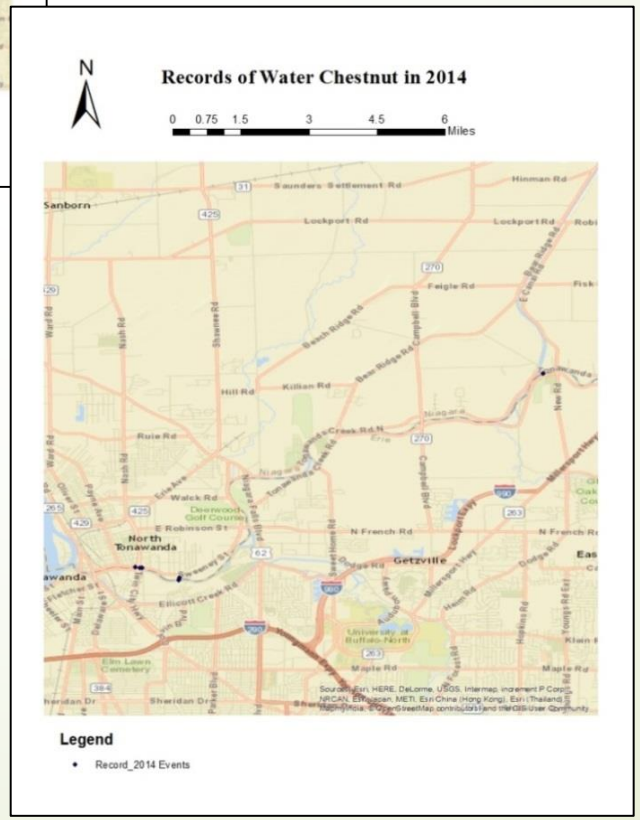
Previous surveys - 2010, 2011

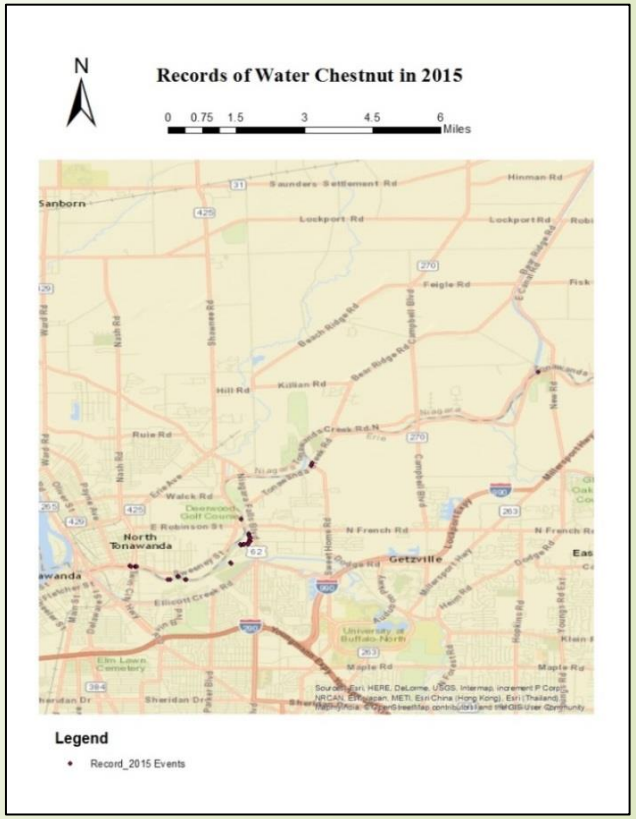




- Previous surveys

- 2012 to 2015

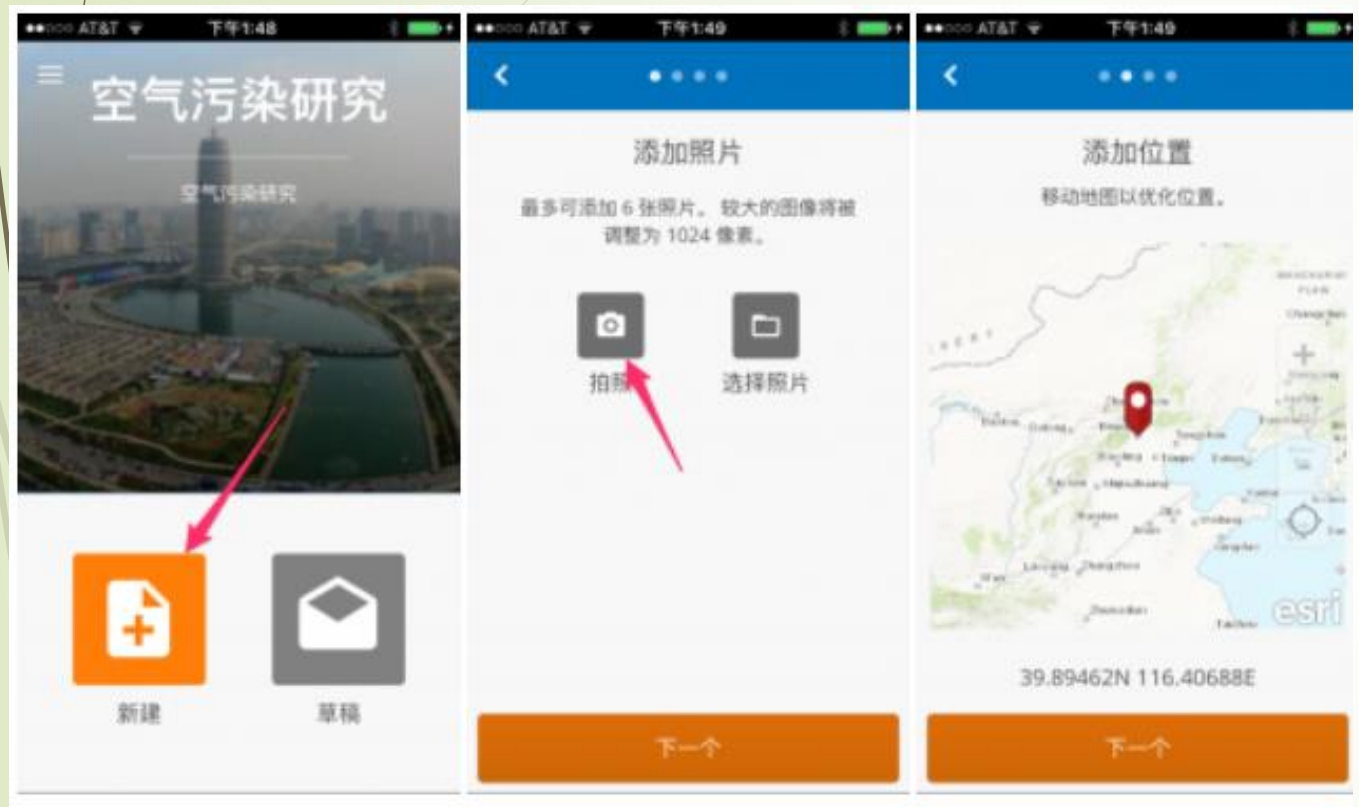




Time sensitive GIS experiment project #3: Smartphone based crowdsourcing survey design for analyzing current air pollution and human health issues - with Mr. Michael Radomski

- The objective of this project is to utilize smartphones equipped with Global Positioning System (GPS) as the sensors to collect large quantity of geographic information on air pollution and human health issues.
- Our study area is Zheng Zhou City, Henan Province, China – obtained a research grant from Henan University.
- This project has three major steps.
- 1) to establish one web page as the platform of smartphone APP downloading to attract a large number of volunteers for data collections.

- 2) to develop one smartphone APP based on survey questions and to utilize the Internet and mobile communication system to establish a centralized data acquisition platform in collecting data for the four seasons during the survey year namely spring, summer, autumn and winter.



- 3) to analyze the data collected using local GIS software and to summarize the results of current problems on air pollution and health issues.

Survey Questions: (During the survey time period, answer twice per day– morning and afternoon)

1. **What do you estimate the air quality of this morning or afternoon 空气质量指数?**

a) 严重污染 (Very heavy pollution)

b) 重度污染 (Heavy pollution)

c) 中度污染 (Medium pollution)

d) 轻度污染 (Light pollution)

e) 良 (Fairly good)

f) 优 (Excellent)

2. **What is the weather of this morning or afternoon do you think?**

a) 晴 (Sunny)

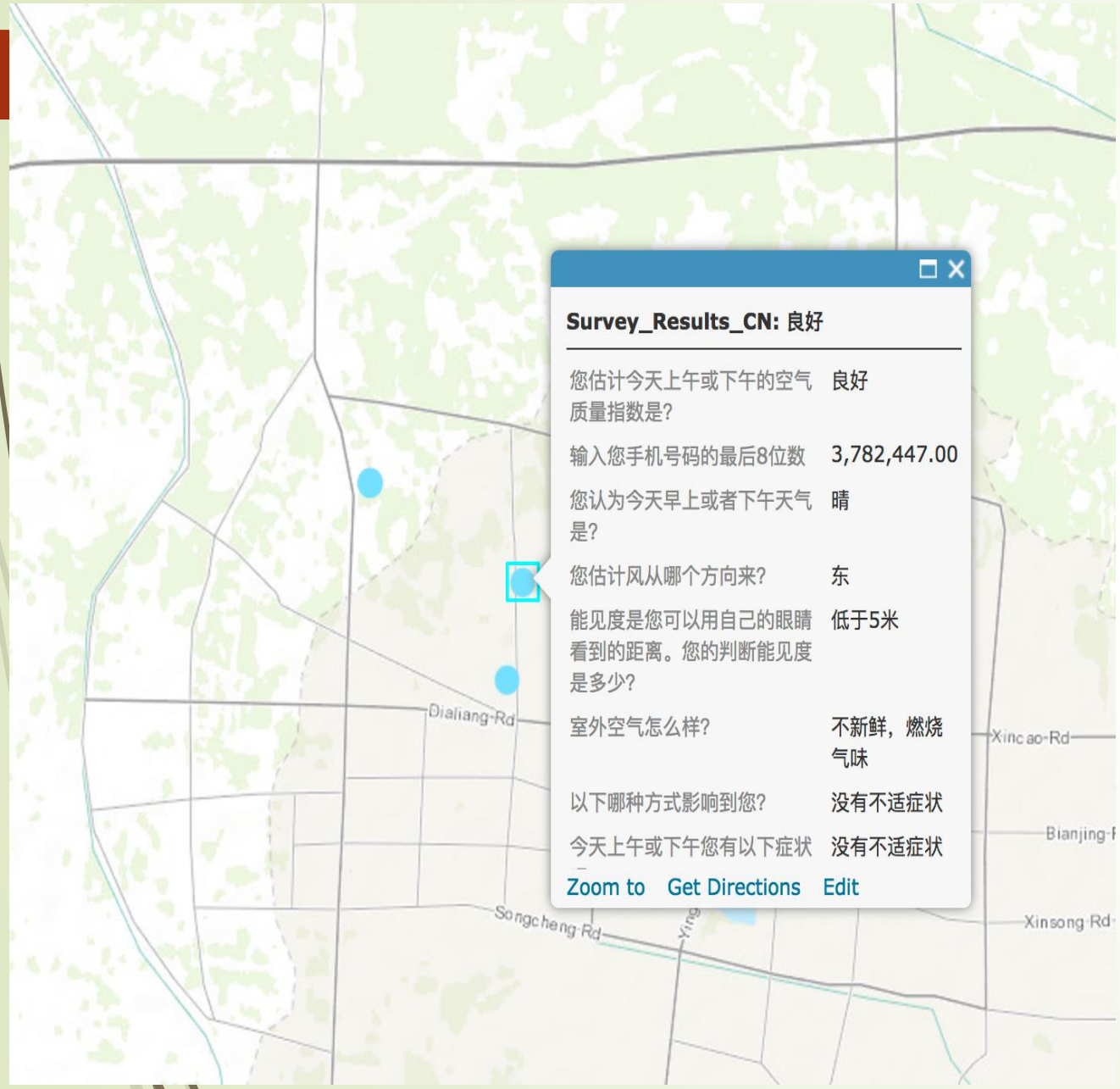
b) 多云 (Overcast sky)

c) 阴 (Cloudy)

d) 小雨(雪) (Light rain or snow)

e) 中雨(雪) (Medium rain or snow)

f) 大雨(雪) (Heavy rain or snow)

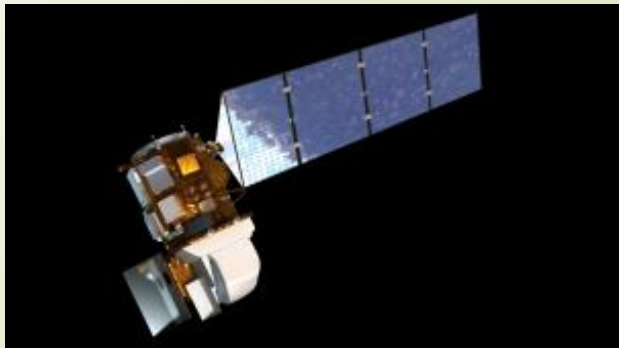


Ideally, large quantity of popular surveying data can be collected and more accurate results than traditional research methods can be reached.

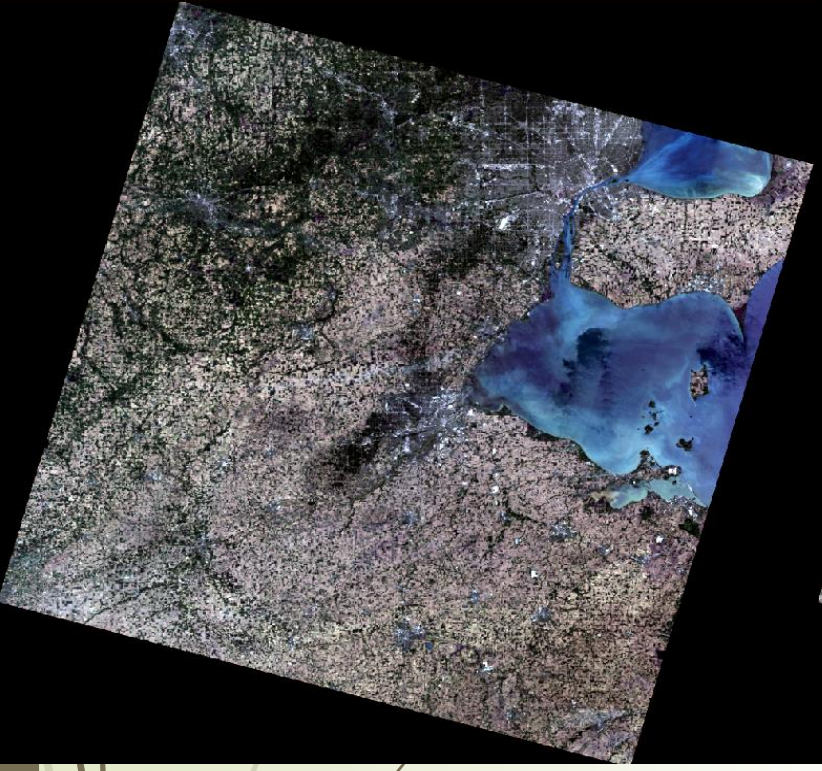
However, the researchers may encounter the credibility and/or popular participation issues interacting with local people that the researchers planned for help.

Time sensitive GIS experiment project #4: Analyzing spatial and temporal changes of algae bloom in the Lake Erie from 2013 to 2016 applying Landsat 8 satellite imagery data

- In order to understand the spatial distributions and changes of concentrated phytoplankton biomass on the lake surface, a total of 28 scenes (frames) of Landsat 8 earth surface observation images at four locations namely Buffalo, Cleveland, Sandusky, and Toledo were analyzed.
- A total of eight images of solar radiation reflection bands were stacked, and subsets of the lake surface areas were extracted from the entire Landsat 8 imagery frame or scene for analyses.
- Both models of the normalized difference vegetation index (NDVI) and the normalized difference water index (NDWI) were used to formulate the algae bloom index in computing and evaluating the distributions and concentrations of phytoplankton biomass on the lake surface at a particular time in the summer seasons.

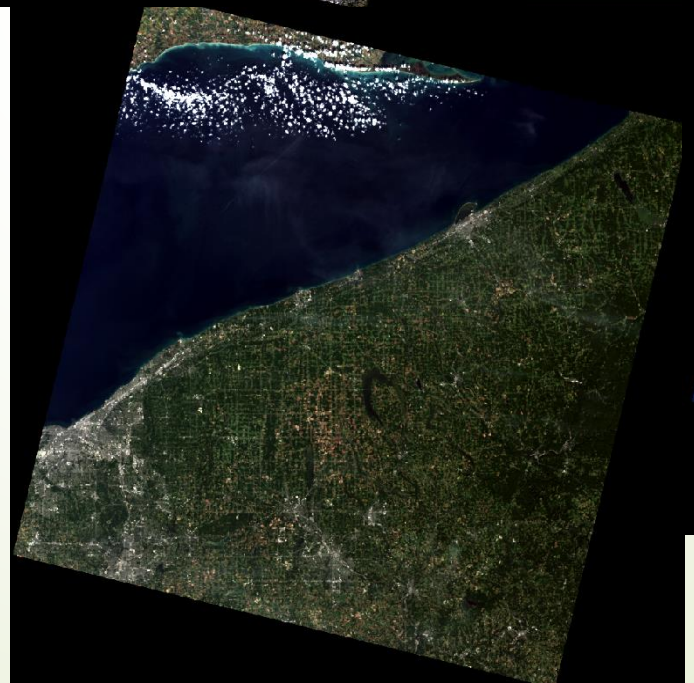


Examples of original Landsat 8 images



Toledo, OH, 06-14-2014

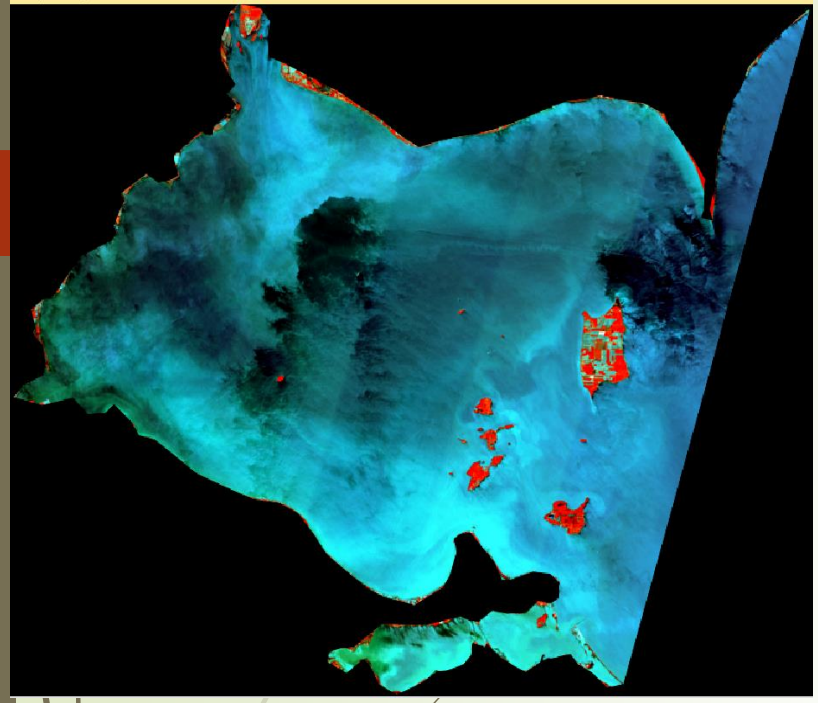
Sandusky, OH, 06-20-2013



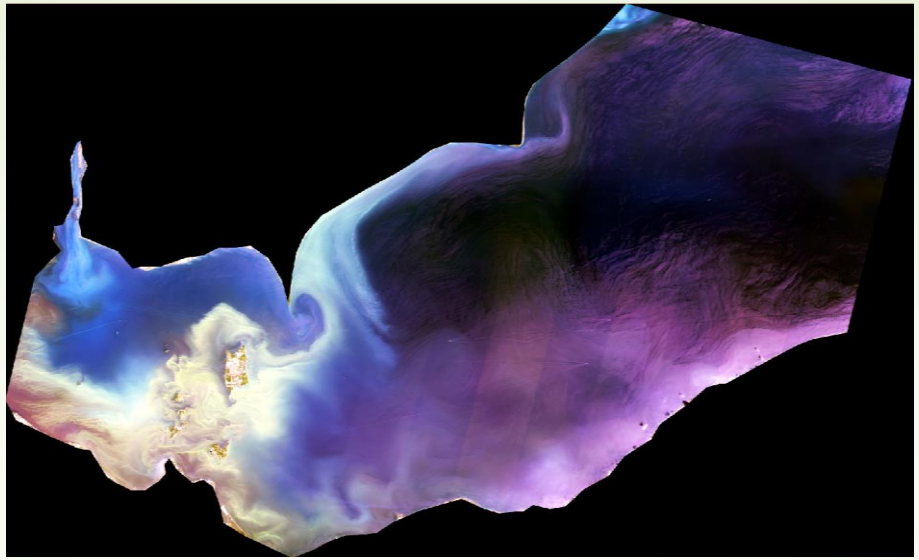
Cleveland, OH, 09-25-2016

Buffalo, NY, 09-16-2015

Examples of the Lake Area Subsets

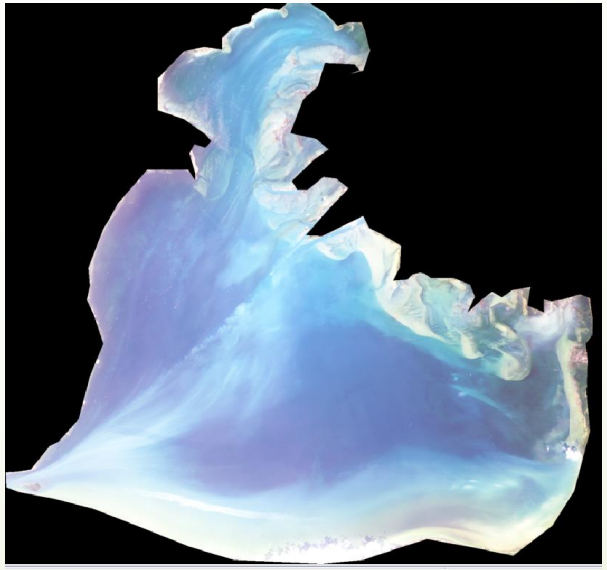


Subset of the lake area,
Toledo, 06-14-2014

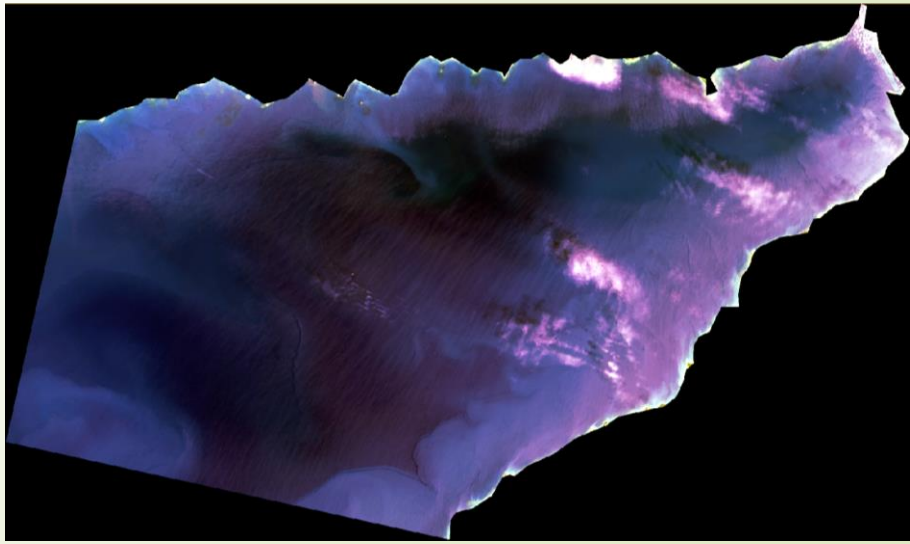


Subset of the lake area,
Sandusky, 07-28-2015

Subset of the lake area,
Cleveland, 09-25-2016

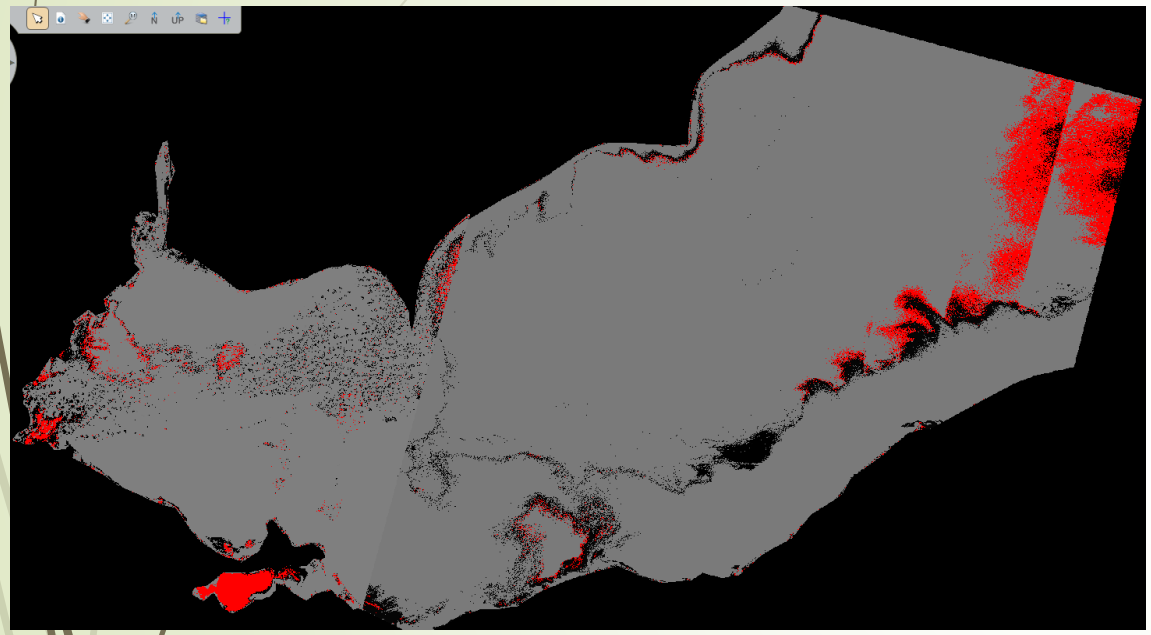


Lake St. Clair,
08-10-2014

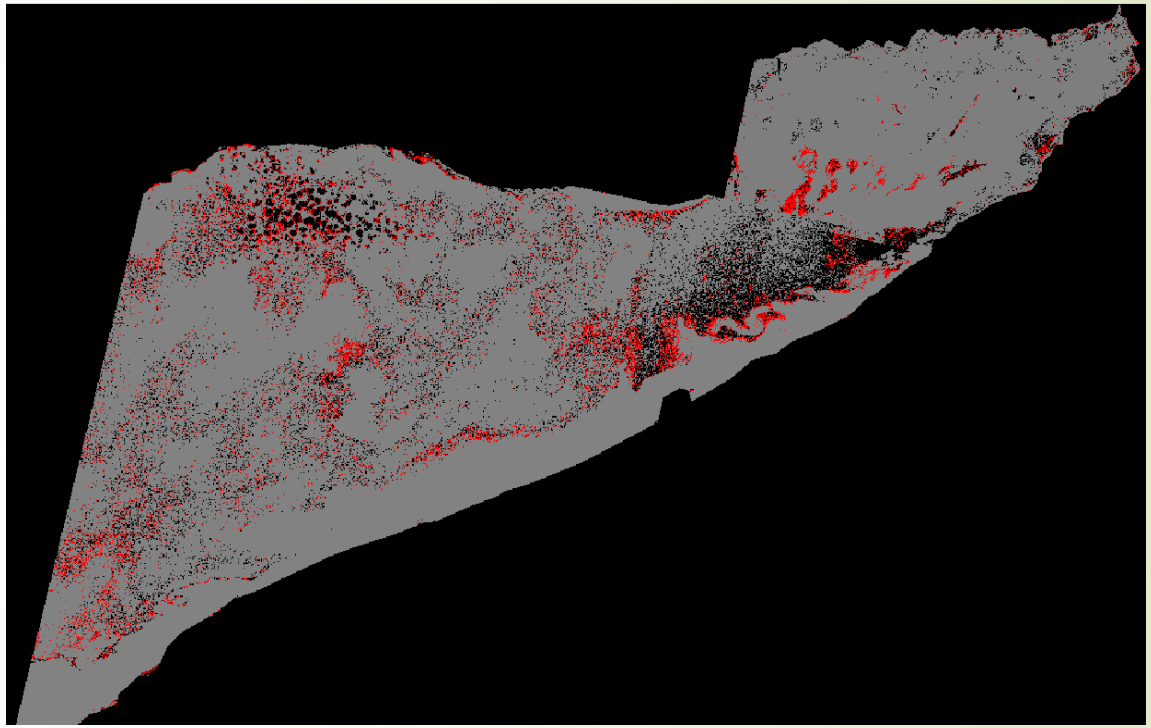


Subset of the lake area,
Buffalo, 06-14-2016

The results indicate that the west and mid-west portions of the lake surface encounter high concentrations of phytoplankton biomass during the summers.

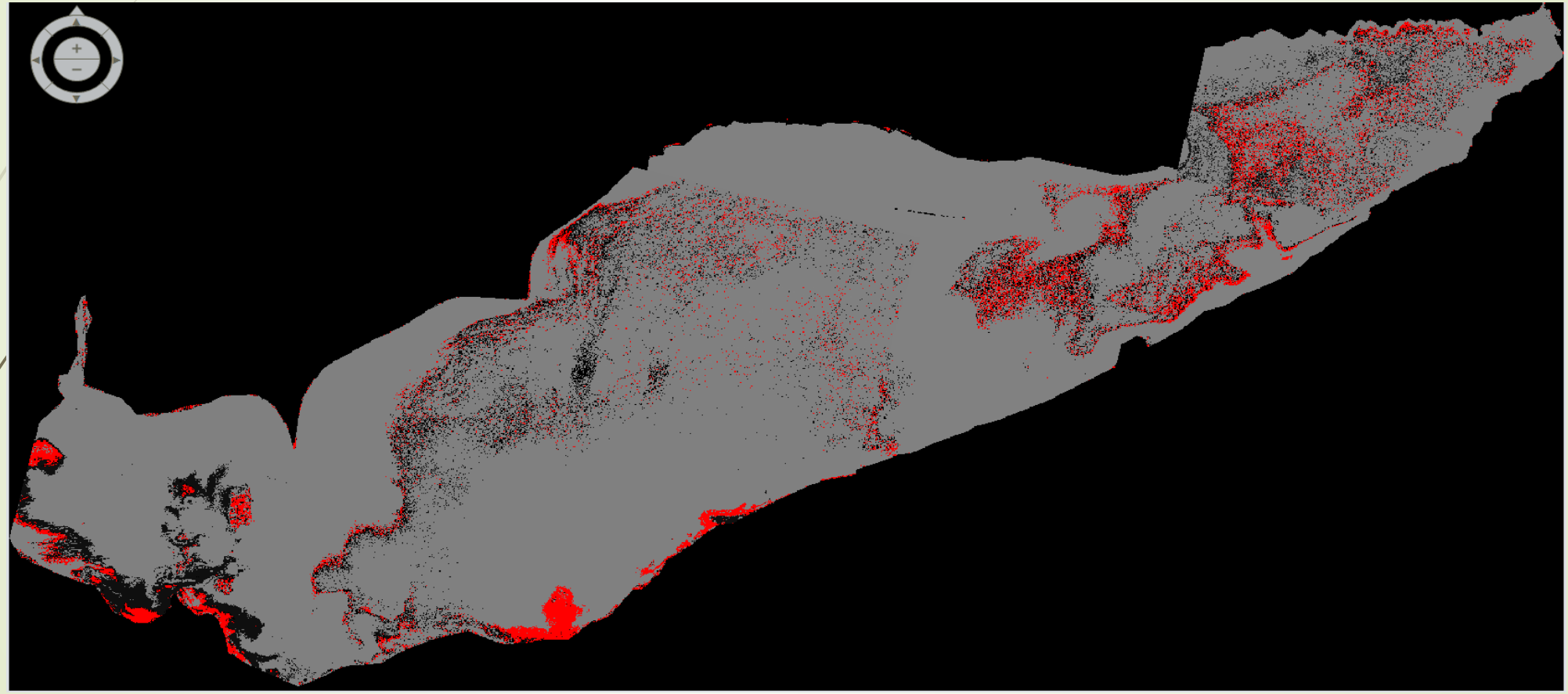


June – July, 2013, Distribution of Algae Bloom Index, the West Lake



September, 2013, Distribution of Algae Bloom Index, the Middle and East Lake

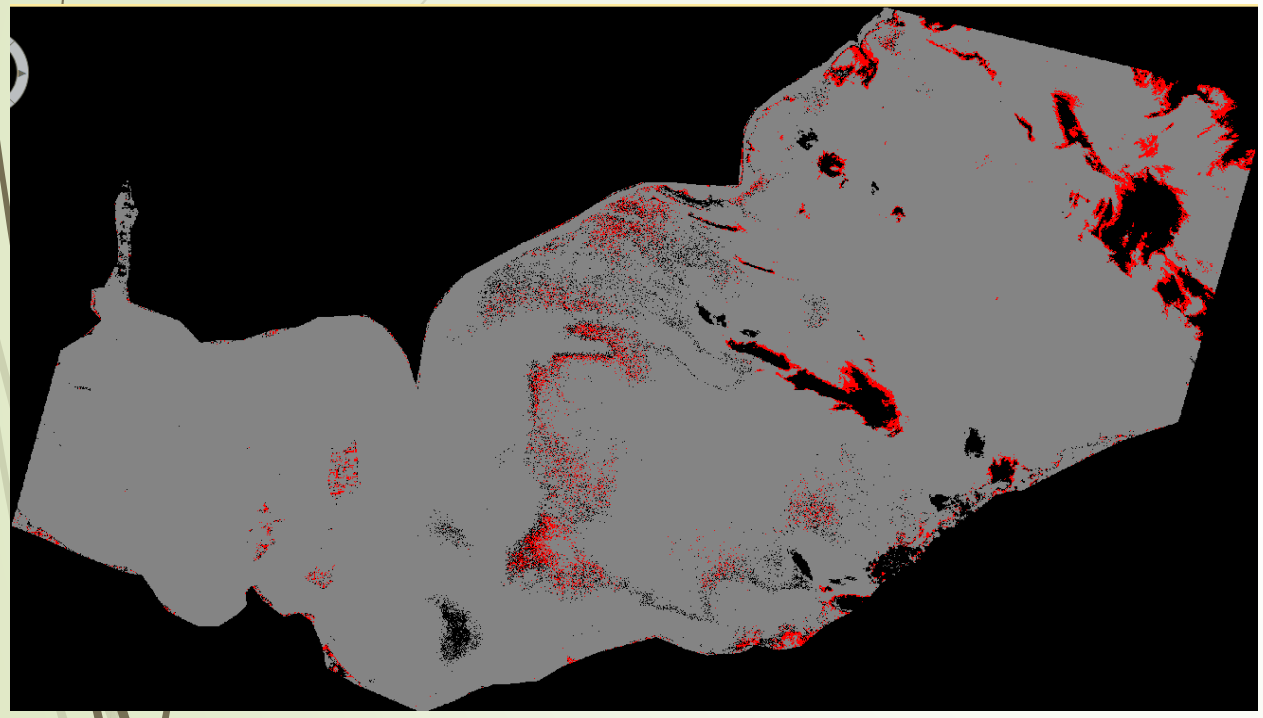
A clear temporal trend exists that the high concentration regions migrate from west end of the lake in the spring and early summer to mid-lake in the middle of the summer, and to the east end towards the end of summer.



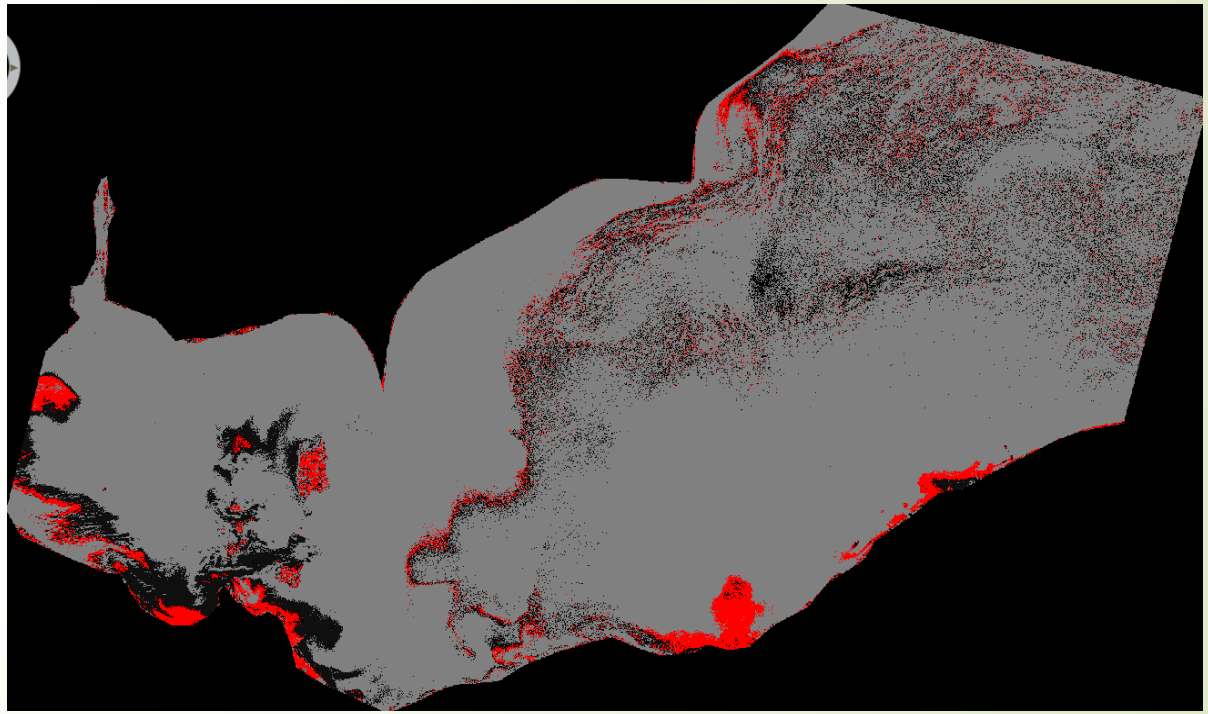
Sandusky, July 28, 2015

Cleveland, September 07, 2015
Buffalo, September 16, 2015

According to the analyses of these datasets, the Lake Erie encountered very significant algal bloom in the summers of both 2014 and 2015. The highest concentration of phytoplankton occurred in the summer of 2015 during the study period.



Sandusky, August 10, 2014

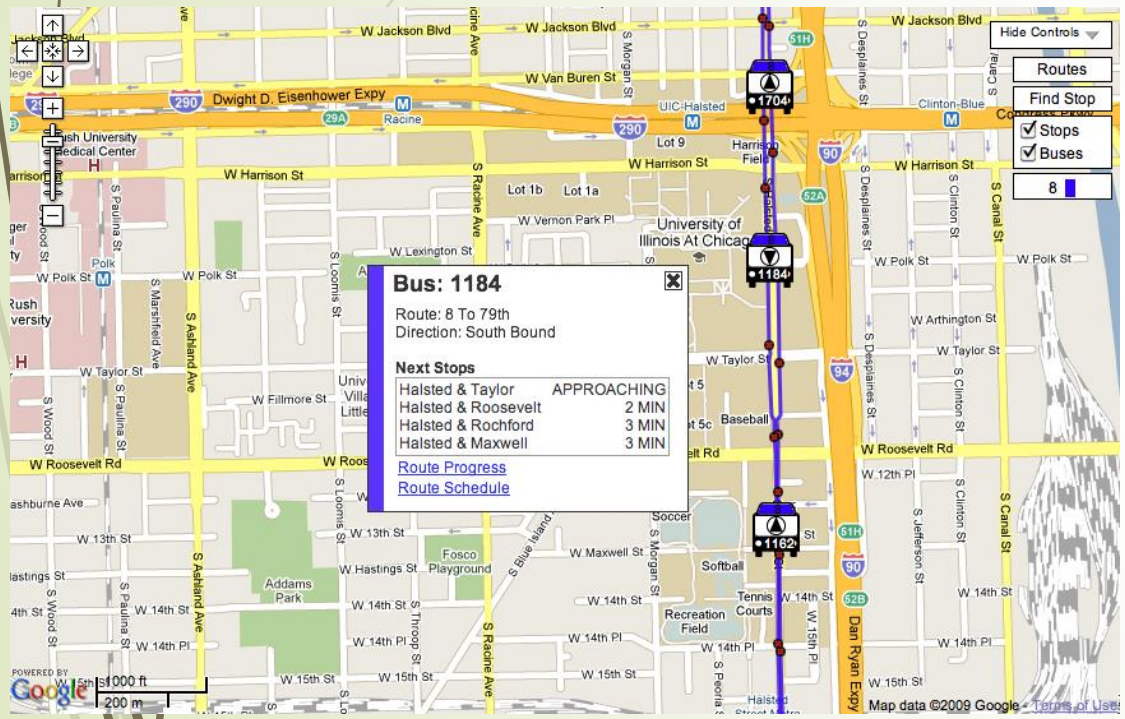


Sandusky, July 28, 2015

Summary and Conclusion

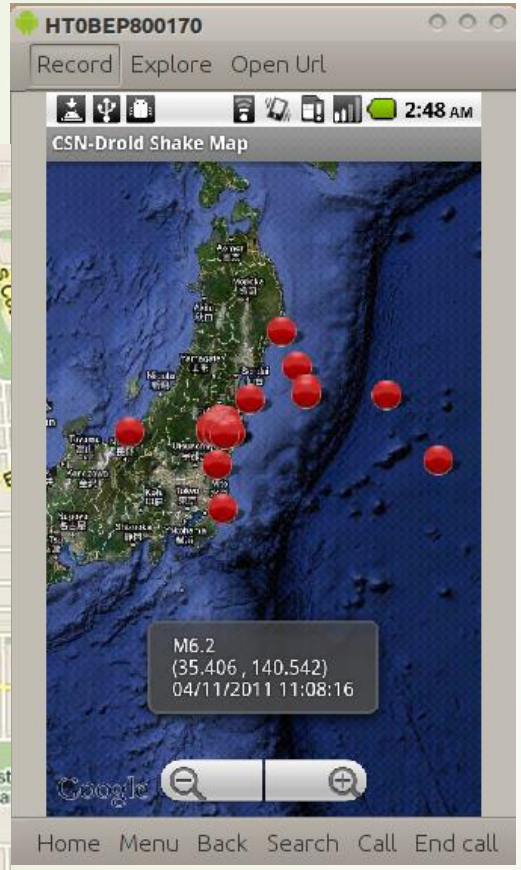
Time scale issues must be considered from data collections, data analyses, data modeling, to data presentations.

- Applications of both in-situ and remote sensors or internet crowdsourcing sensors must consider the time scale issues and time sensitive issues.



- CTA Live Bus Route Sensing and Digital Mapping

Both spatial and time scales are significant in GIS data collection, Data analyzing, and geographic event modeling

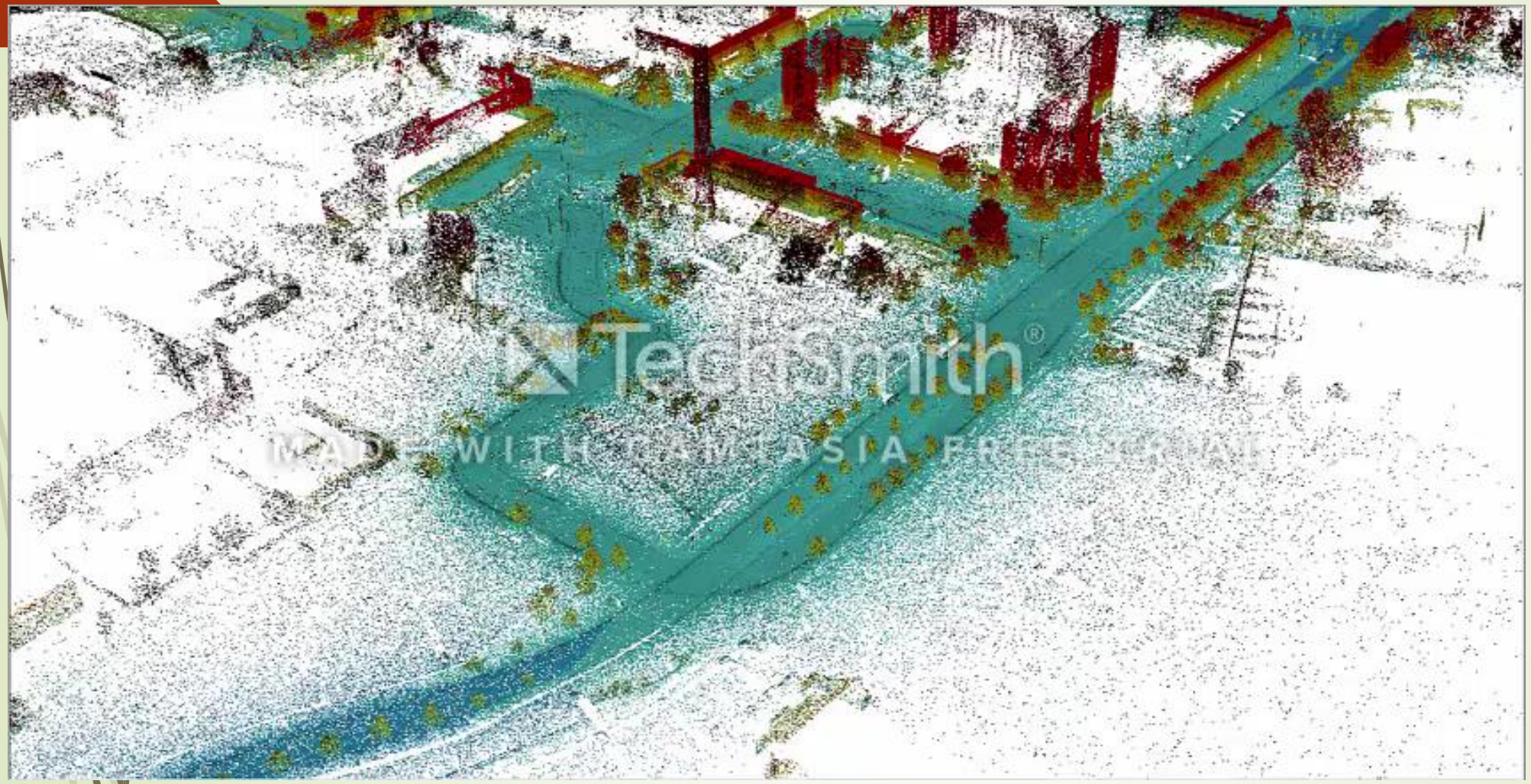


- Geographic processes or events are both spatial- and time-dependent.
- More research needs to be conducted on brief (small) time scale or concurrent geographic processes and events at various spatial scale levels.
- Time scale sensitive sensor development and applications either in-situ, remote, or at online websites are very useful and important.

A few examples:

1) Earthquake prediction
2) Traffic and travelling route condition broadcasting and planning
3) Forecasting and analysis of the spread of infectious diseases

THANK YOU! QUESTIONS?



Flying through SUNY - Buffalo State College campus using ground LiDAR data collected by Dr. Tao Tang, and compiled by Mr. Michael Radomski

Acknowledgement: many thanks to the New York State Great Lakes Research Consortium for a research grant