MAPPING MICHIGAN'S VERNAL POOLS WITH MULTI-SOURCE REMOTE SENSING

Michael Battaglia, Laura Bourgeau-Chavez, Dorthea Vander Bilt, Rod Chimner, Samantha Kurkowski

Michigan Tech Research Institute
Michigan Technological University

2023 MWA Wetlands Conference
Kalamazoo • MI | September 13, 2023

Michigan's Vernal Pools

- Vernal pools are small, seasonally inundated, hydrologically isolated, forested depressions found throughout the midwestern and northeastern United States.
- They provide critical amphibian and invertebrate breeding grounds, and habitat for a wide range of other flora and fauna.
- Vernal pools are underrepresented in wetland inventories because of their small size and typical location beneath forest canopies.
- Conservation of these important ecosystems requires a more complete understanding of their abundance and location.

Challenges of Vernal Pool Identification

- Field surveys are time consuming and costly, multiple visits are required to confirm a topographic depression's status as a vernal pool.
- Some areas are difficult to reach or completely inaccessible.
- Typical methods of remote detection rely on visual interpretation of air photos, which can be difficult, especially when imagery from only one or two dates is available.
- Can we use other sensing technologies to help us identify vernal pools?

Vernal Pool Characteristics that can be Detected with Remote Sensing

- Vernal pools occur in small topographic depressions that lack a permanent connection to other bodies of water.
- Vernal pools typically fill with water from snow melt and precipitation in springtime, then dry out during the summer.
- These characteristics provide requisite conditions for vernal pool indicator species to reproduce, as the isolation and drying cycle means that the pools are usually fishless, which limits the threat of predation.

Wood Frog

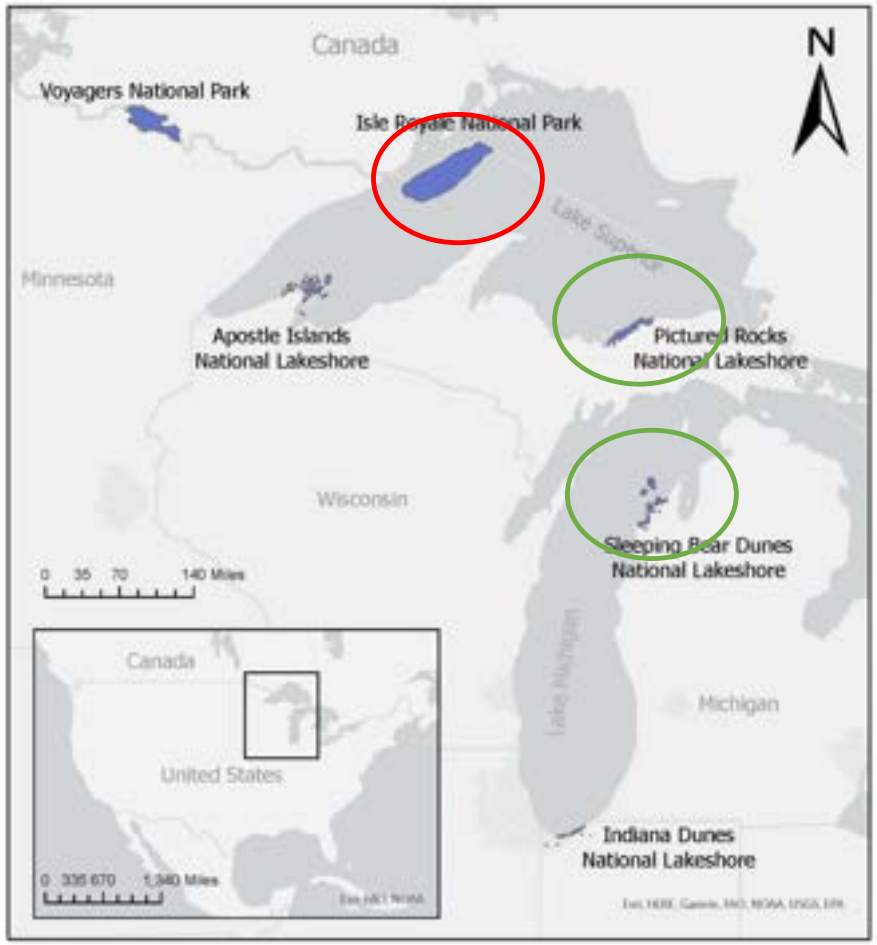
Blue-Spotted Salamander

Fairy Shrimp

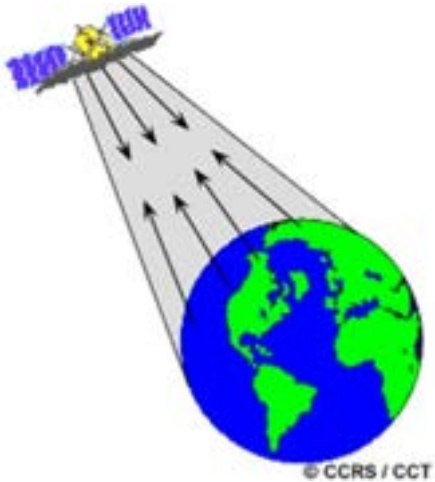
National Parks Vernal Pool Mapping

Project Goals

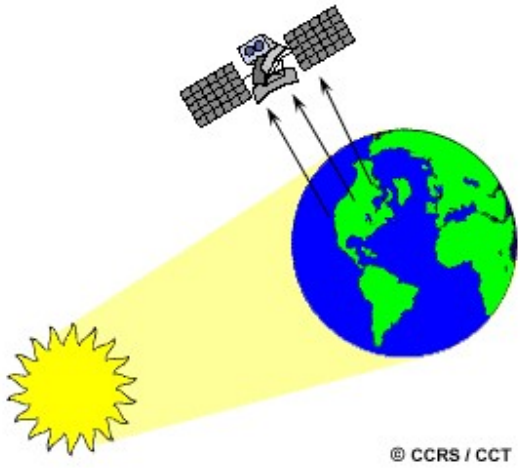
- Advance previous vernal pool mapping methods to reduce errors (omission & commission) using multi-source remote sensing for National Parks and Lakeshores in the Great Lakes.
- Conduct field surveys to verify vernal pool status and collect additional data.
- Use field data to develop a vernal pools classification system.



Remote Sensing Overview



Active sensors provide their own energy to illuminate the object or scene they observe. They send a pulse of energy from the sensor to the object and then receive the radiation that is reflected back. SAR and Lidar are examples of active remote sensing.



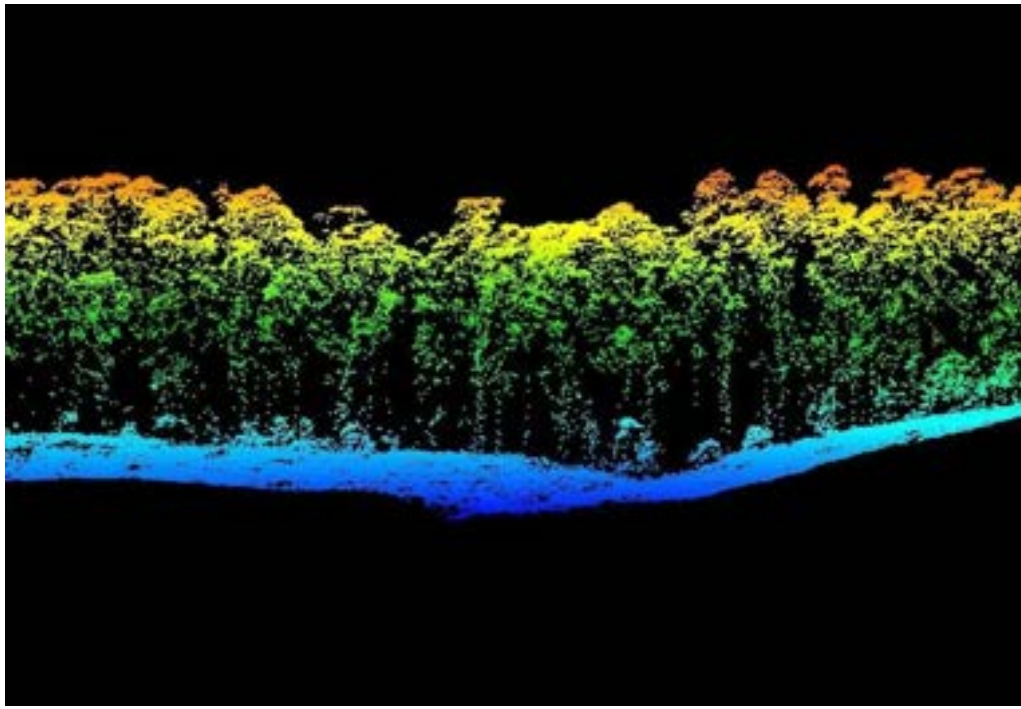
Passive sensors sense radiation emitted or reflected by an object. The sun is the most common source of radiation for passive remote sensing. Infrared and visible images are examples of passive remote sensing.

Remote Sensing Overview: Optical and CIR imagery

- High resolution optical and near infrared images are captured by sensors onboard airplanes.
- Vegetation foliage, water, soil, and manmade surface each reflect light differently, giving unique characteristics that result in different tones in air photos.
- Vegetation obscures the surface beneath, making it difficult to assess the presence of water.

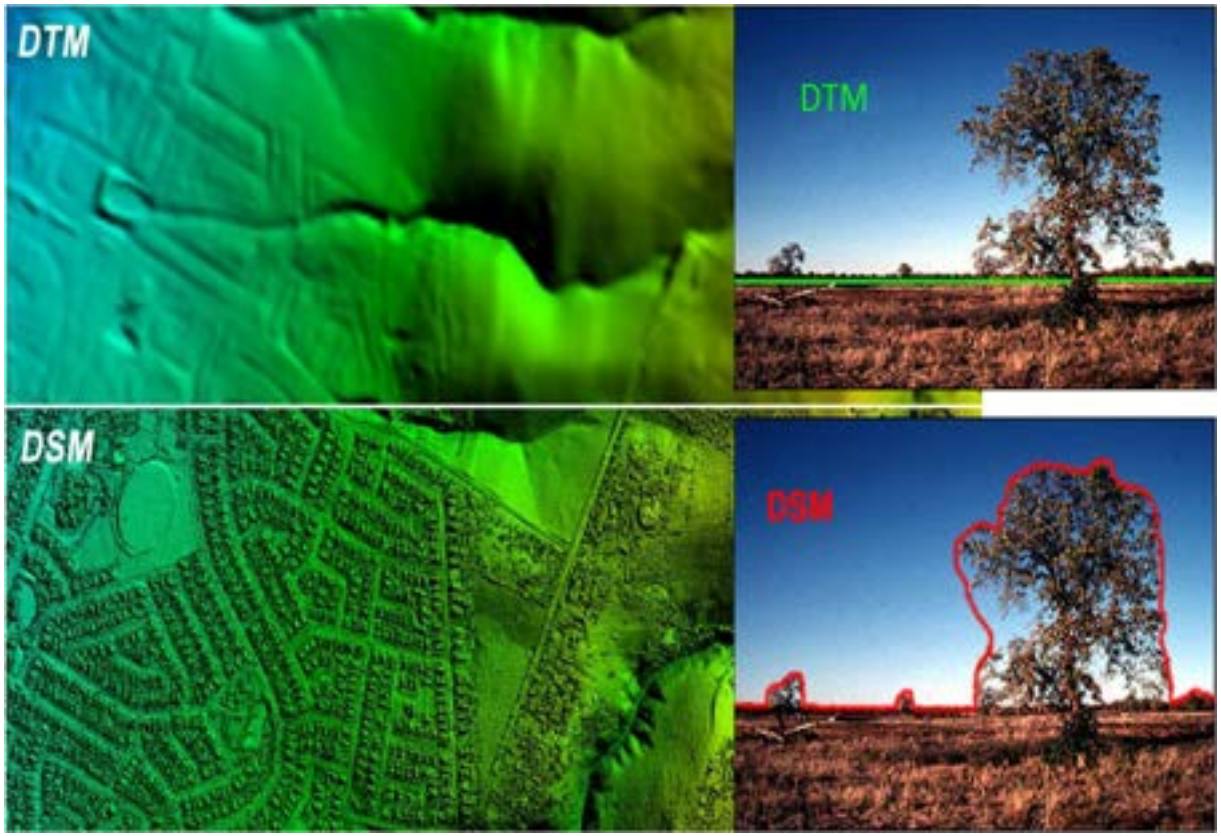
Remote Sensing Overview: Lidar

- Lidar sensors emit pulses of light (typically in the near-infrared portion of the spectrum) which interact with objects directly below on the earth's surface.
- The time it takes for the pulses to return to the sensor is recorded, along with the intensity of the returning pulse.
- Data is provided as a "point-cloud" where each point is attributed with a value representing elevation.



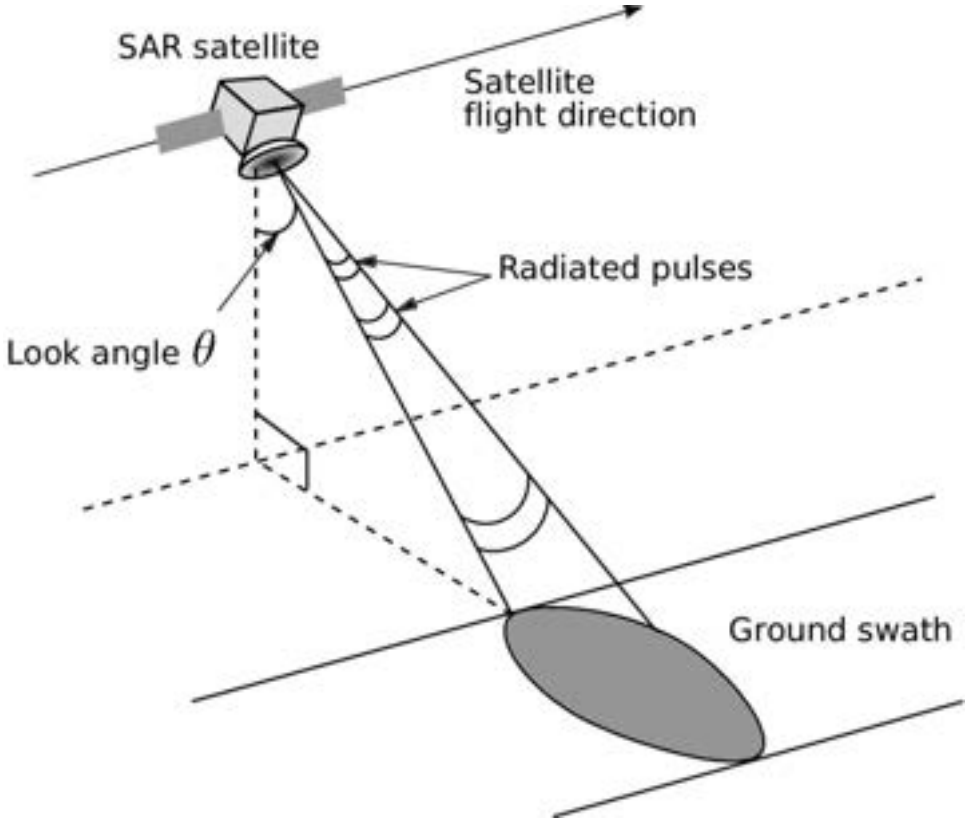
Remote Sensing Overview: Lidar

- Point clouds can be classified into “first returns” which represent top-of-canopy elevation, and “last returns” which represent the ground.
- These are then converted to Digital Terrain Models and Digital Surface Models.



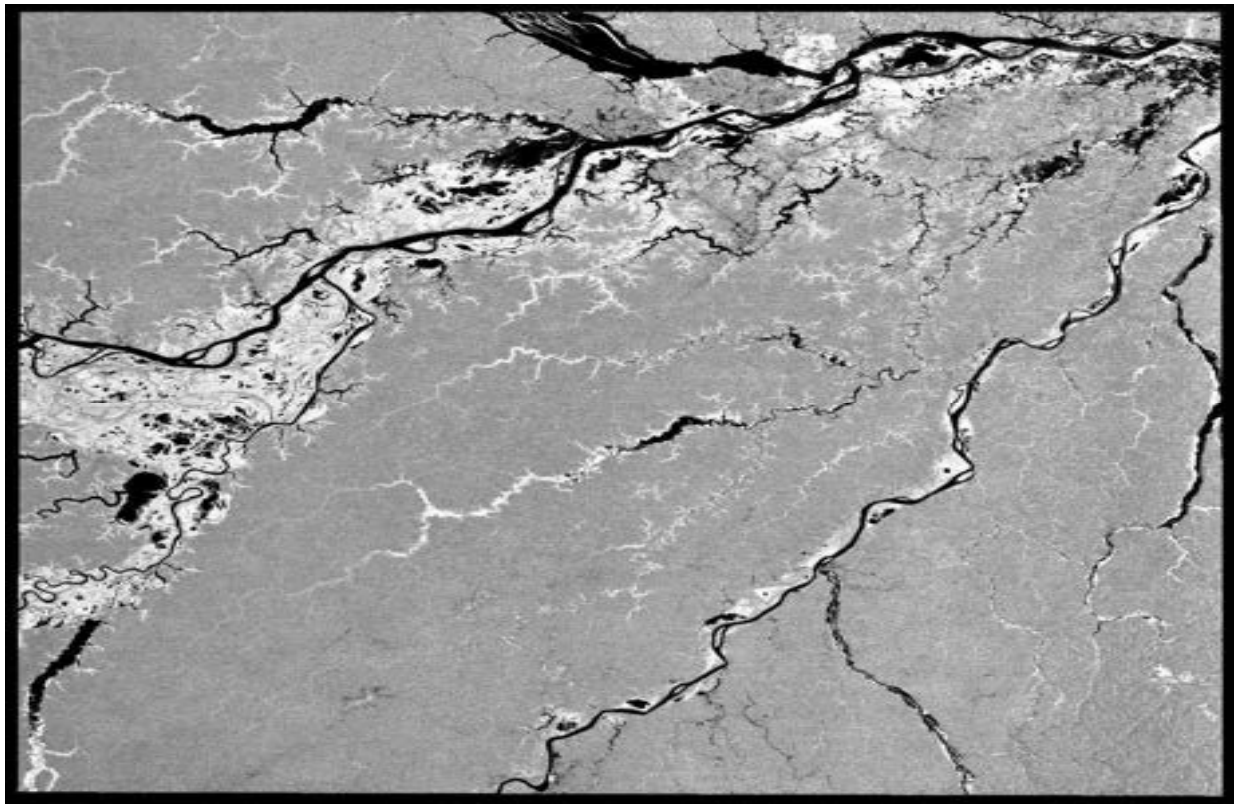
Remote Sensing Overview: SAR

- Radars are active sensors that transmit microwave radiation in pulses then record backscattered energy.
- SARs are side facing, so their energy interacts differently with the objects on the earth's surface.
- Backscattered intensity is the most common metric used to assess the environment with SAR.

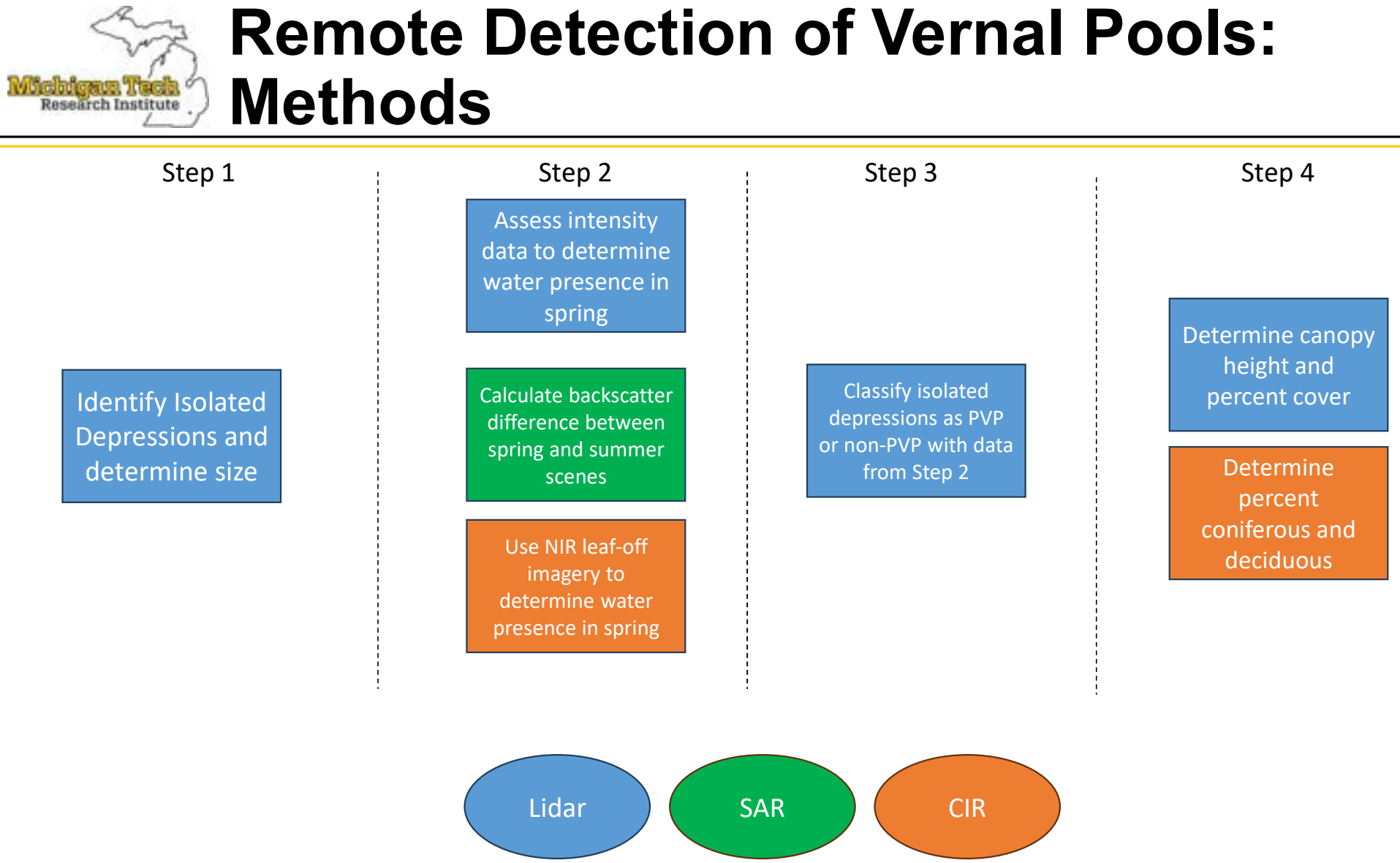


Remote Sensing Overview: SAR

- Different objects interact with microwave radiation in different ways.
- The way different land cover types scatter energy can provide information on whether or not the area being imaged is flooded, even in the presence of vegetation.

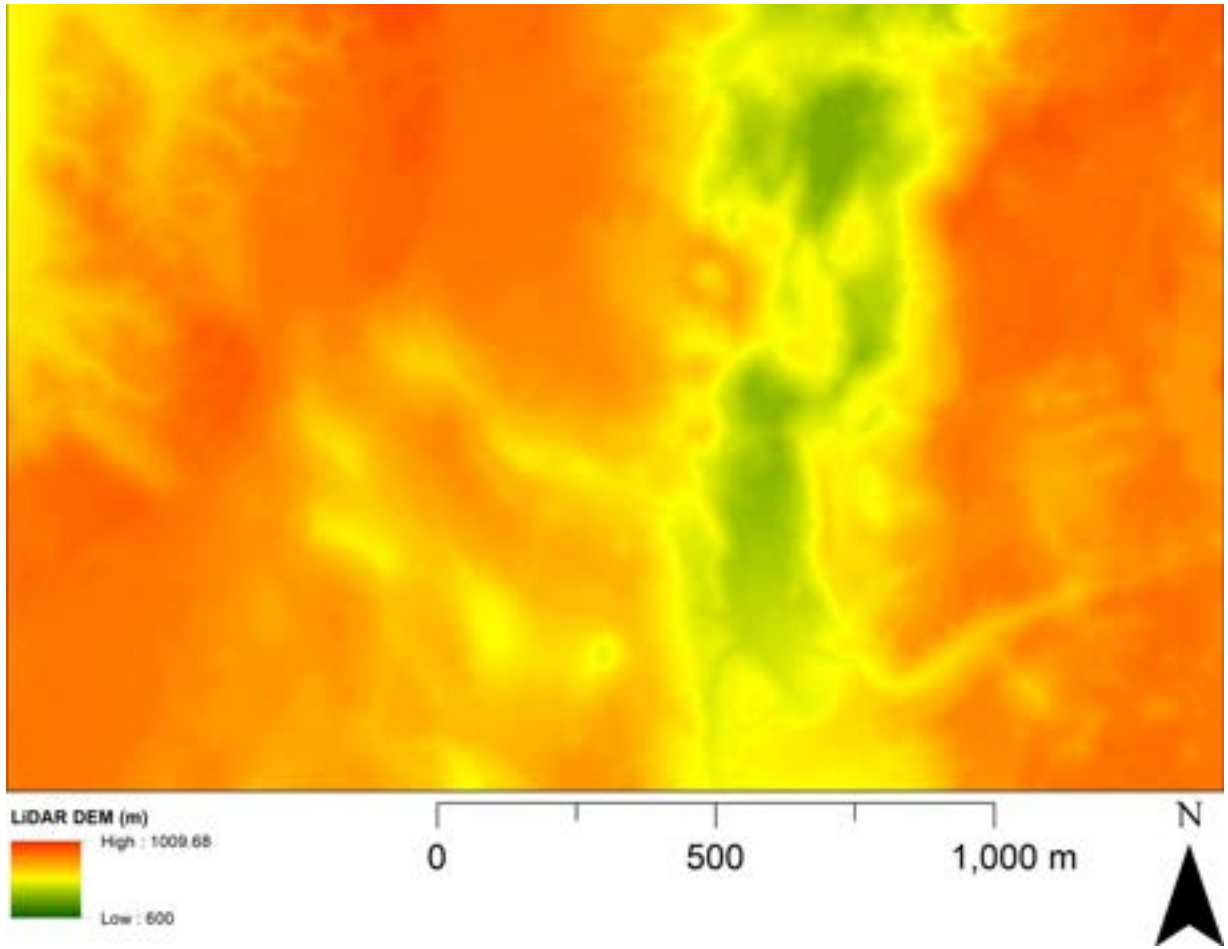


Remote Detection of Vernal Pools: Methods



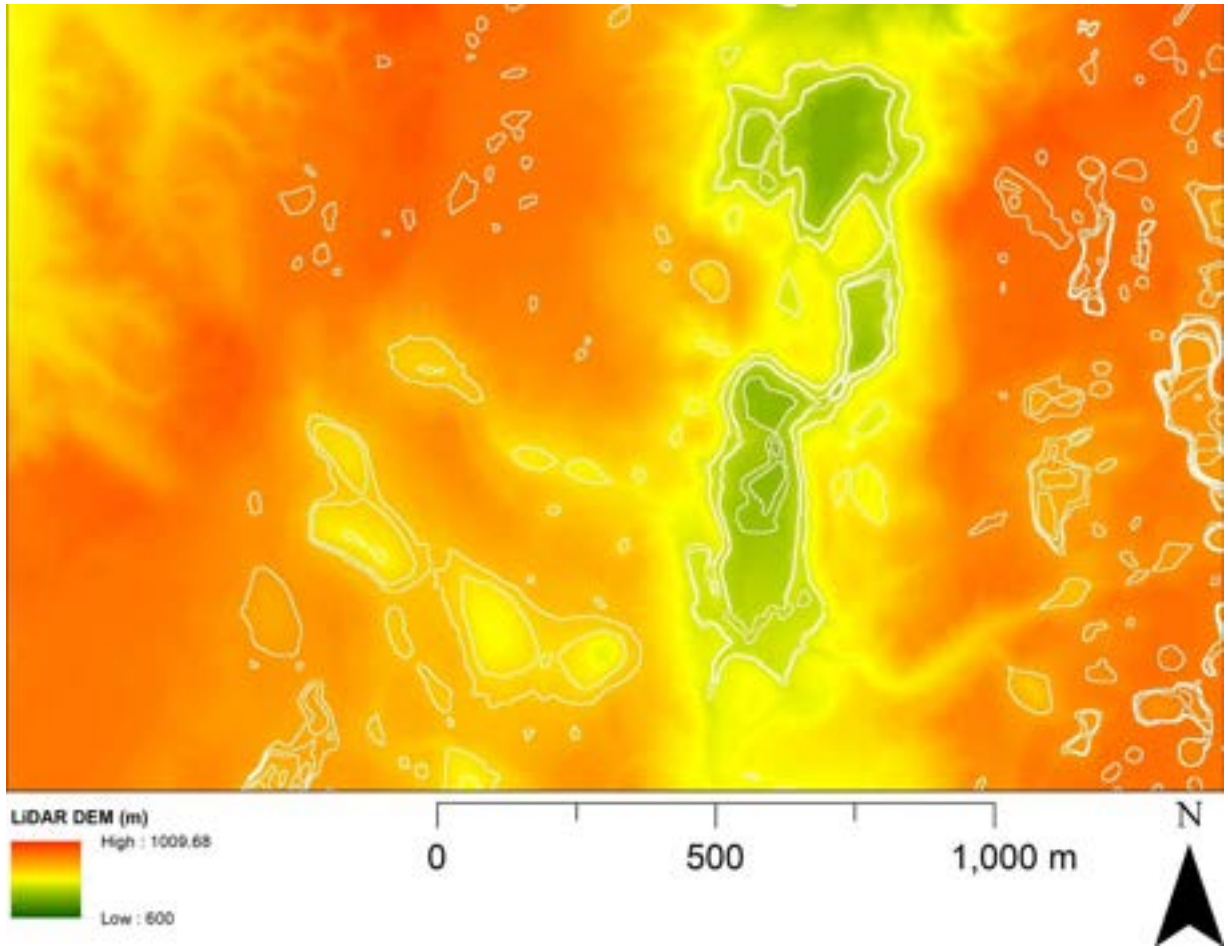
Step 1: Isolated Depressions

- LiDAR sensors send pulses toward the ground. The time it takes for the pulse to bounce off of the ground and return to he sensor is used to measure elevation



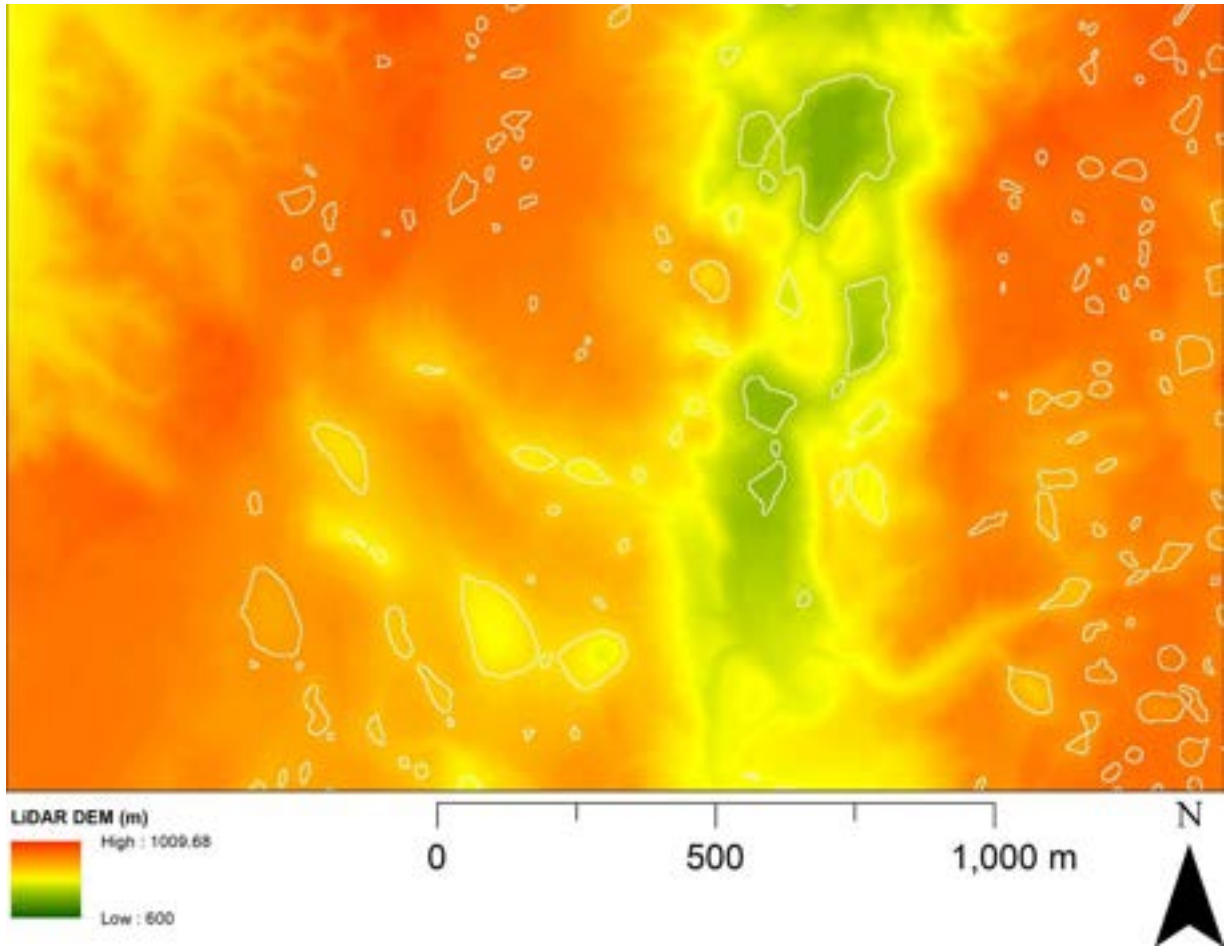
Step 1: Isolated Depressions

- A contour tree approach (Wu et al. 2015) is used to identify depressions which, based on their morphology, have no outflow
- The algorithm uses contours within each identified depression to find “nested” depressions, i.e. depressions within larger basins



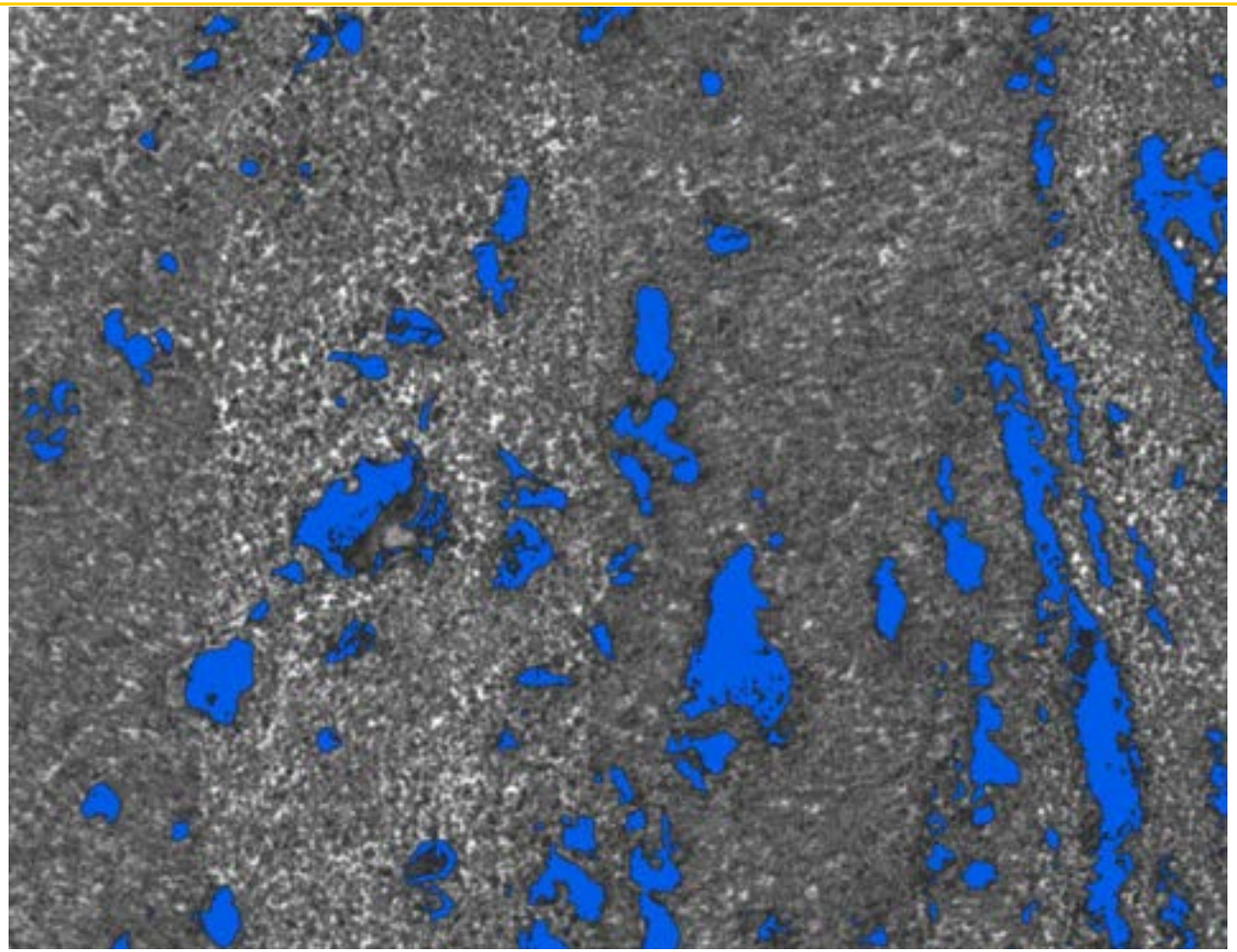
Step 1: Isolated Depressions

- The innermost depressions (classified as “level 1”) are selected for further analysis
- Using this approach allows us to assess the area of the small, isolated depressions, and eliminate any that don’t fit our size criteria (>1ha)



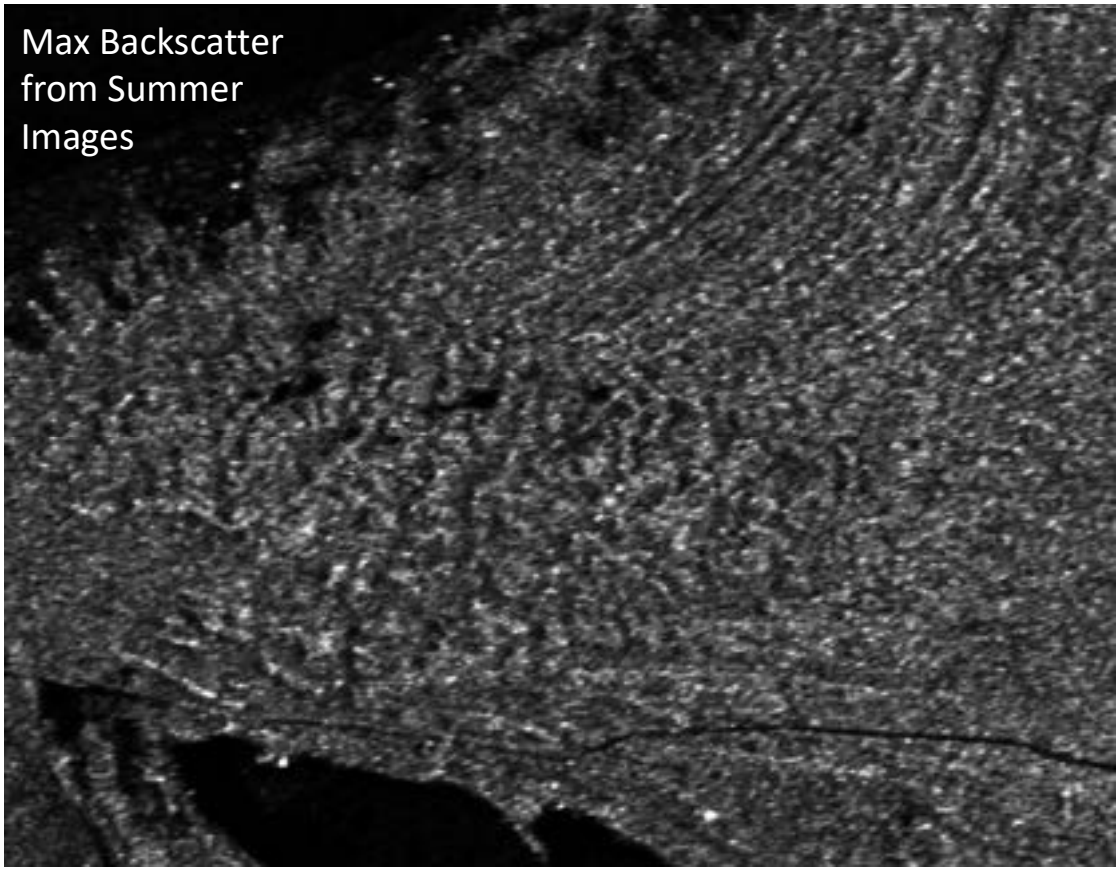
Step 2: Lidar hydroperiod assessment

- In addition to measuring elevation, LiDARs can measure the strength of the signal that returns to the sensor
- Most LiDARs emit near-infrared laser pulses
- Since near-IR light is mostly absorbed by water, the intensity signal from flooded areas is typically very low
- We use this signal to infer inundation in vernal pools

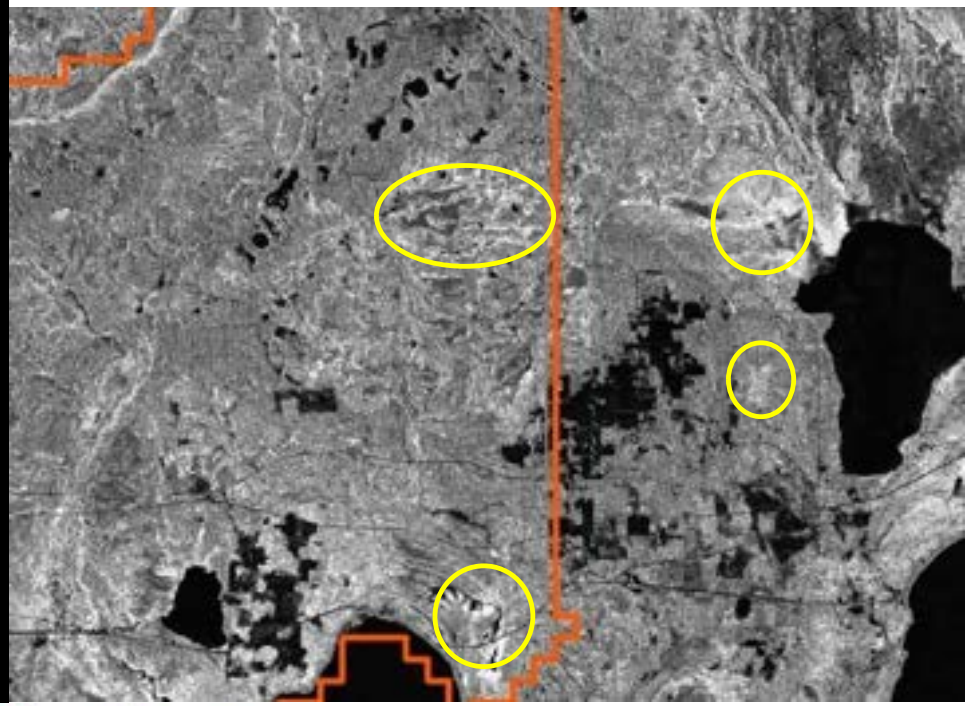


Step 2: SAR hydroperiod assessment

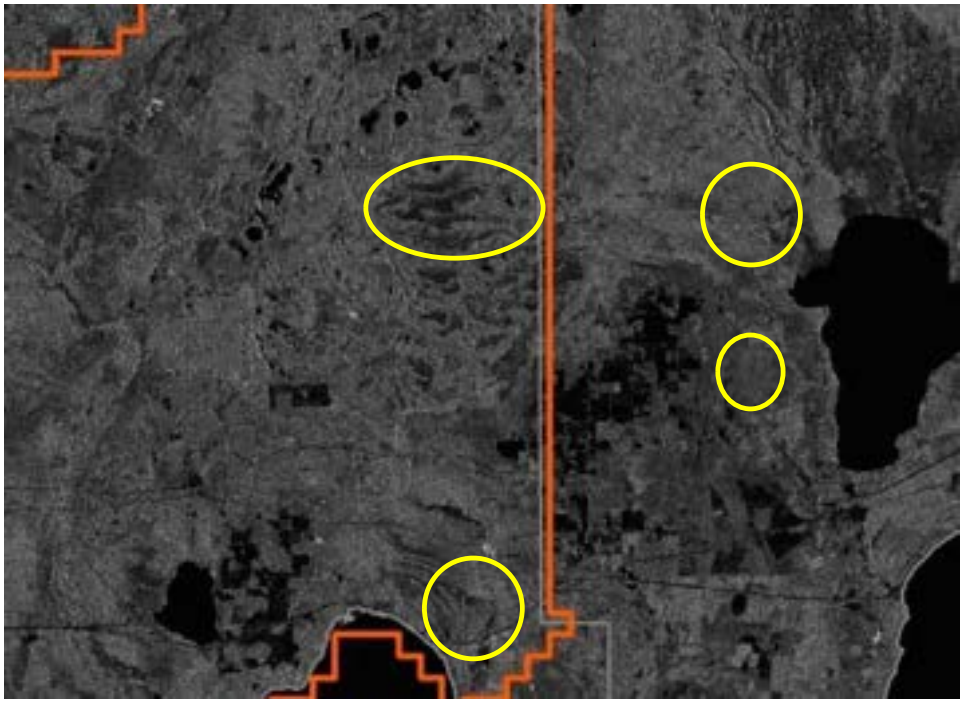
- Flooded forests will appear bright in the imagery due to a characteristic “double bounce,” while open water appears black and non-flooded areas appear shades of grey
- The difference between spring and summer backscatter can be exploited to give information on if and when vernal pools dry out.



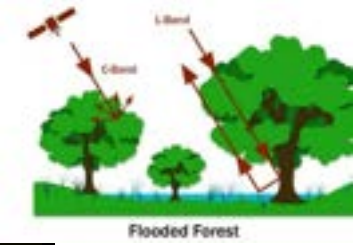
Step 2: SAR hydroperiod assessment

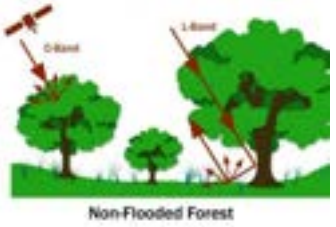


April 20, 2008



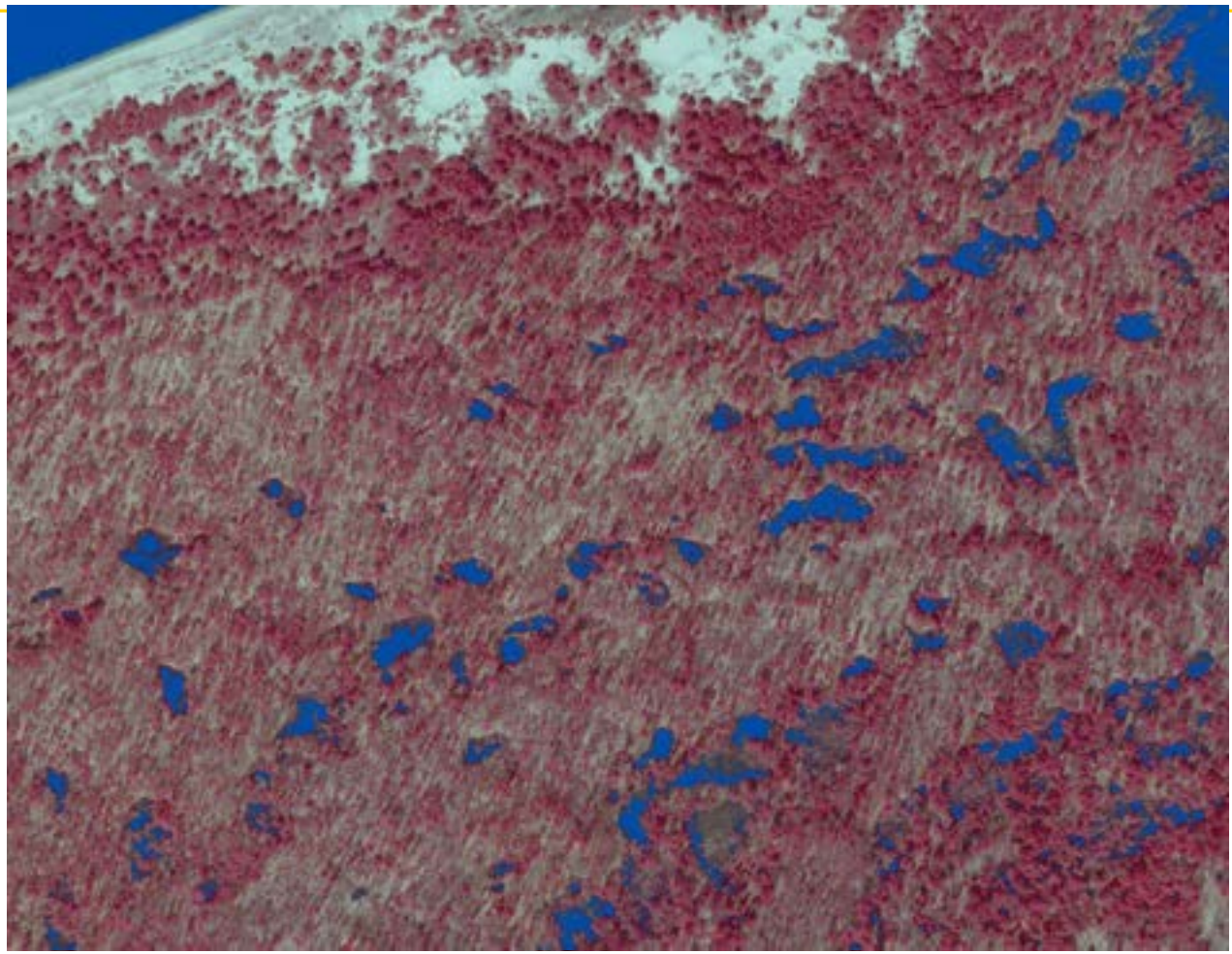
August 14, 2015





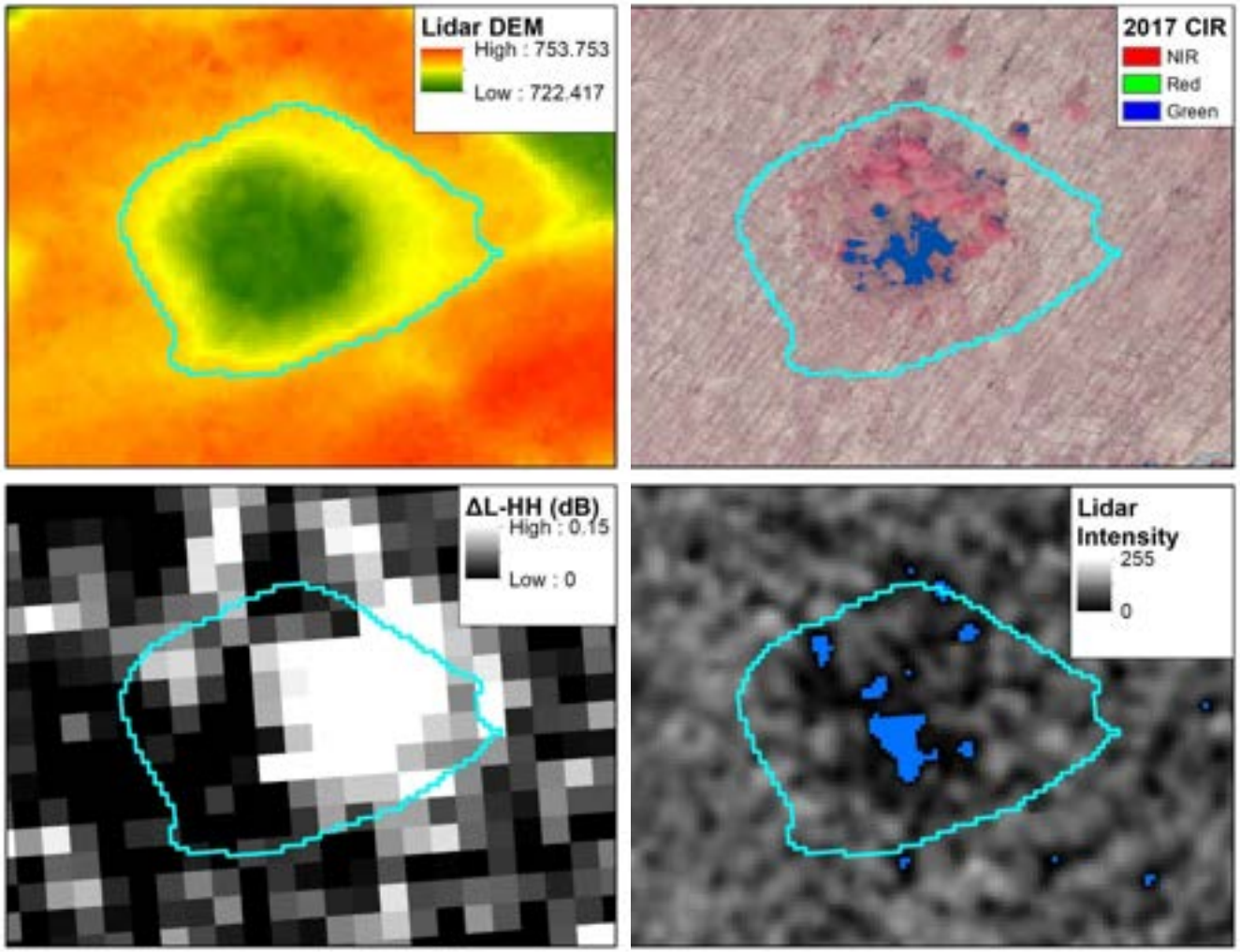
Step 2: CIR photography hydroperiod assessment

- Similar to the near infrared LiDAR pulses, water absorbs much of the near infrared light emitted by the sun
- When CIR imagery is collected we can use it to determine where water is present by finding areas of low NIR reflectance



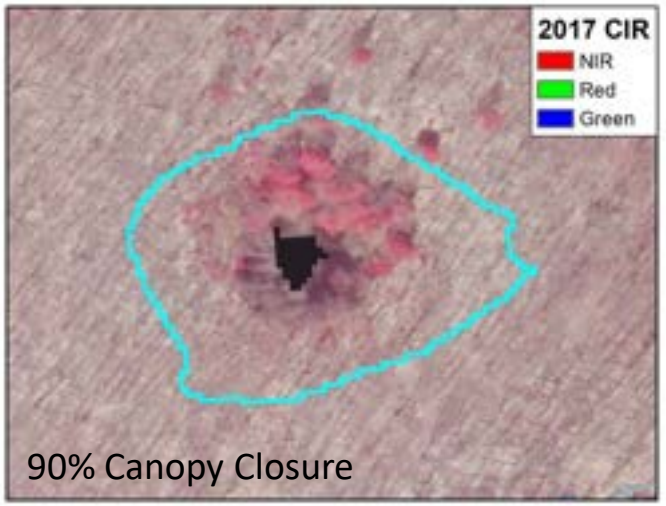
Step 3: PVP Classification

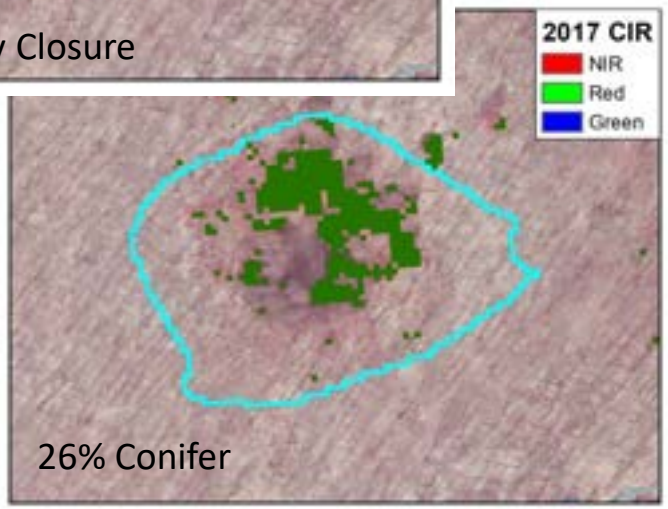
- For each polygon representing an isolated depression, metrics are calculated from the SAR data, LiDAR data, and CIR data
- For each sensor in which the depression exhibits water presence, it is attributed with a 1
- The values are summed across the sensors to determine the number of times the data showed water presence
- Depressions with values 1-3 are classified as potential vernal pools
- The example at right has a value of 3, indicating it is likely to be a vernal pool



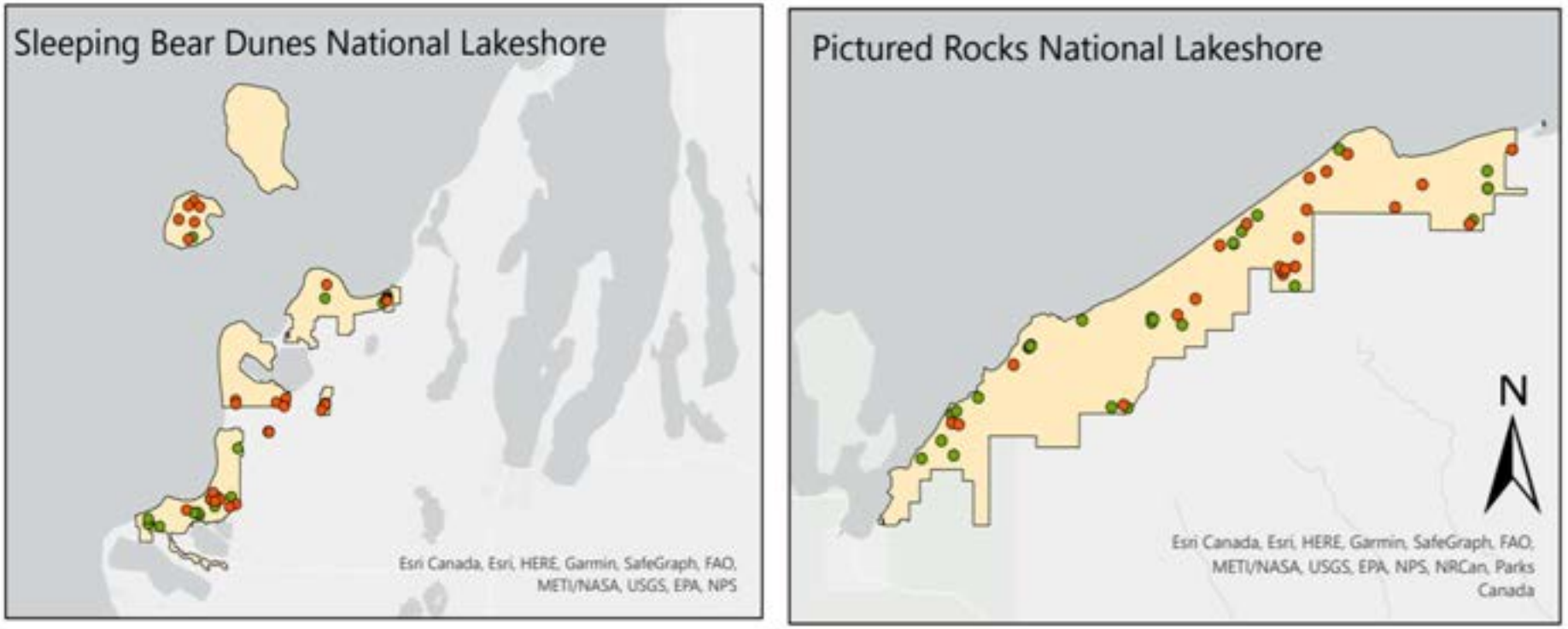
Step 4: Additional PVP Characteristics

- Lidar derived vegetation heightcan be used to determine estimates of canopy closure
- NDVI calculated from leaf-off color infrared aerial photography used to differentiate deciduous from coniferous dominance
- This ancillary information from the LiDAR and CIR data is assigned to each polygon representing a potential vernal pool
- It's size and volume (calculated with LiDAR data) is also included in the attribute table





Field Sampling



Field Sampling Protocol

Applied MVPP sampling protocol with additional sampling of soils and floristic species.

Spring sampling included:

- water depth, pH, pool size, cover, surrounding vegetation, soil organic depth, mineral depth, soil samples
- Indicator species (wood frogs, fairy shrimp, spotted salamanders, fingernail clams) and predators (fish, bullfrogs)

Summer sampling included:

- Revisit pools labeled as “potential vernal pools” from spring measurements (were isolated, fishless, indicator species present)
- water conditions (depth, size of pool if not dry), vegetation in and around pools, etc.

Vernal Pool Monitoring Form

Modified- for NPS 2020 - Standard MVPP Monitoring Data Form

Michigan Vernal Pools Project

Michigan Natural Features Inventory | Michigan State University Extension

Vernal Pool Patrol Hub - Contact MNFI at (517) 284-6200

QC Date: ____ QC Initials: ____ Data Entered: ____

1a) Observer Information [x] Visit 1 [ ] Visit 2 [ ] Visit 3 Time: from ____ [ ] AM [ ] PM to ____ [ ] AM [ ] PM

Name(s): Lauren, Dorothea, Andrew Date: 4-30-21

1b) Property Information Ownership? [ ] Public [ ] Private Landowner/Manager Name: SBNP

Site name: SB Address:

Plot # 3819 City: State: Zip:

2a) Vernal Pool Location Was pool mapped as a Potential Vernal Pool (PVP)? [ ] Yes [ ] No

Pool ID # 3819 New Pool ID #

Enter coordinates in Decimal Degrees (e.g. Latitude 44.78402 Longitude -73.65422)

Township/Range/Section/1/4 info: Latitude: 44.707911N Longitude: 86.186421W

County: For verification of PVP location please enter names and coordinates for the nearest crossroads. Record as Decimal Degrees as shown above.

Method for locating pool? [ ] In the Field Latitude: Longitude:

[ ] GPS [ ] Topo Map [ ] Google Earth [ ] Air Photo Crossroad names:

2b) Brief Site Directions to Pool **

trail

** Written site directions to pool (This should include (1) description of a logical starting point, (2) the distance from the starting point to pool, (3) the direction of travel, and (4) distinctive landmarks and water bodies). For example: Enter Robin Hood Park on the trailhead at Jordan Road. Follow the trail west approximately 1/2 mi. This is the first pool on your left, just behind a low stone wall.

3a) Pool Type Is this a Vernal Pool? [x] Yes [ ] No [ ] Not Sure Pool Photo Numbers

[ ] Open Pool [ ] Sparsely Vegetated Pool [ ] Shrubby Pool

[x] Forested Pool [ ] Marsh Pool [ ] Other (describe):

3b) Presence of Inlet or Outlet

Is this pool isolated or connected to a part of another water feature? [ ] culvert [ ] lake [ ] open/emergent/shrubby wetland

[x] Yes, pool is isolated [ ] No, pool is connected to: (check ALL that apply) [ ] stream [ ] ditch [ ] forested wetland [ ] vernal pool

If inlet/outlet is present, indicate type: [ ] permanent [ ] temporary [ ] do not know [x] none

3c) Surrounding Habitat (within 100 feet of pool) (check ALL that apply)

[ ] Upland Deciduous Forest [ ] Lowland Deciduous Forest **Disturbances:** [ ] Powerline right-of-way [ ] Other:

[ ] Upland Coniferous Forest [ ] Lowland Coniferous Forest [ ] Agriculture [ ] Light development (<25%) [ ] No disturbances

[x] Upland Mixed Forest [ ] Lowland Mixed Forest [ ] Road/driveway [ ] Intensive development (>25%)

[ ] Floodplain [ ] Grassland or open [ ] paved [ ] Minor logging (>or = 70% canopy remaining)

[ ] Emergent Wetland (marsh, bog) [ ] dirt/gravel [ ] Major logging (<or = 70% canopy remaining)

4a) Approximate Maximum Pool Depth

[ ] Ankle-deep (<6") [ ] Hip-deep (2-3 ft)

[ ] Shin-deep (6-12") [ ] Chest-deep (3-4 ft)

[x] Knee-deep (12-24") [ ] Deeper than 4 ft

4d) Approximate Size of Pool (at maximum capacity - at widest and longest points)

Width: 14.5 m ~~feet~~

Length: 21.5 m ~~feet~~ hypsometer

Size determined by: [ ] Pacing [x] Measuring [ ] Using GPS

4b) Water Level at Time of Survey (check one)

[x] Full/Nearly full 75-100% [ ] Less than half 25-49%

[ ] Partially full 50-74% [ ] Dry/mostly dry 0-24%

4c) Water temperature (°F): 8.8°C

4e) Substrate (when dry - check ALL that apply)

[ ] Leaf litter [x] Sand - Gravel [ ] Unknown

[ ] Bedrock [x] Muck - Peat [ ] Other:

[ ] Loam [ ] Silt - Clay

Soil #513 ...

4f) Vegetation in Pool

Are there trees >or =4" in diameter present in the basin? (check one)

[ ] No [x] Yes, within pool basin [ ] Yes, but only at the edge

#of trees only within the pool basin? 4 [x] live and/or [ ] dead/snags

% Cover within the pool (check one)

Floating vegetation: [x] 0% [ ] 1 to 9% [ ] 10 to 25% [ ] 26 to 50% [ ] >50%

Emergent vegetation: [ ] 0% [x] 1 to 9% [ ] 10 to 25% [ ] 26 to 50% [ ] >50%

Shrubs: [ ] 0% [x] 1 to 9% [ ] 10 to 25% [x] ~~26 to 50%~~ [ ] >50%

Tree canopy over pool basin (when leaves are fully out): [ ] 0% [ ] 1 to 9% [ ] 10 to 25% [x] 26 to 50% [ ] >50%

4h) Cover (Any material in the pool that can provide egg attachment sites and offer concealment to adults and/or larvae: check all that apply)

[x] Shrubs [x] Submergent vegetation

[x] Branches, twigs [x] Logs or large woody debris

[ ] Sphagnum moss [x] Emergent vegetation (grasses, cattails)

[x] Algae [ ] Other:

[x] Leaf litter

4g) Pool Disturbance (in pool, immediately adjacent or along shore of pool - check all that apply)

[ ] Dumping - Refuse [ ] Filling [ ] Invasive Species Present

[ ] Ditching - Draining [ ] Sediment [ ] Purple loosestrife [ ] Garlic mustard

[ ] Agricultural runoff [ ] Vehicle ruts [ ] Reed canary grass [ ] Other:

[ ] Cultivation - Livestock [ ] Presence of rock pile or other anthropogenic disturbance [x] No disturbances

5) Indicator Species and Additional Species (If other species are observed please list below in blank fields under Fingernail Clams)

Provide a photograph of each indicator species (adults, juveniles/larvae, or egg masses) observed. **Photos of species observed are required.**

Species Observed	Adults	Tadpoles/Larvae	Egg Masses			Photo? Yes	Notes/Photo ID#
			Number	Estimated	Counted		
Wood Frog				[ ]	[ ]	[ ]	
Spotted Salamander			2	[ ]	[x]	[ ]	egg masses pic 171-178
Blue-spotted Salamander				[ ]	[ ]	[ ]	
Fairy Shrimp							1
Fingernail Clams			1+5				pic 178
Spring peeper	1			[ ]	[x]	[ ]	
				[ ]	[ ]	[ ]	
				[ ]	[ ]	[ ]	
				[ ]	[ ]	[ ]	
				[ ]	[ ]	[ ]	
				[ ]	[ ]	[ ]	
				[ ]	[ ]	[ ]	

Were any of the following observed? (check ALL that apply)

[ ] Fish: (indicate all lengths observed) [ ] <3" [ ] >3" [ ] Green frogs: [ ] tadpoles [ ] adults

[ ] Bullfrogs: [ ] tadpoles [ ] adults [x] Other: spring peeper adult

Comments:

Water color: brown pH: 6.47

Pool condition (circle): poor good excellent

Ash tree presence (y/n): y % Ash trees dead: 100

All trees in pool are ash dark layer 9 cm

individual/few/several [ ] 1000 ft^2 (half tennis court) [ ]

1000 ft^2 to 0.5 acre [ ] 0.5 acre to 1 acre [ ] >1 acre [ ]

Restoration potential:

disturbance easily fixed, site in fair to poor condition [ ]

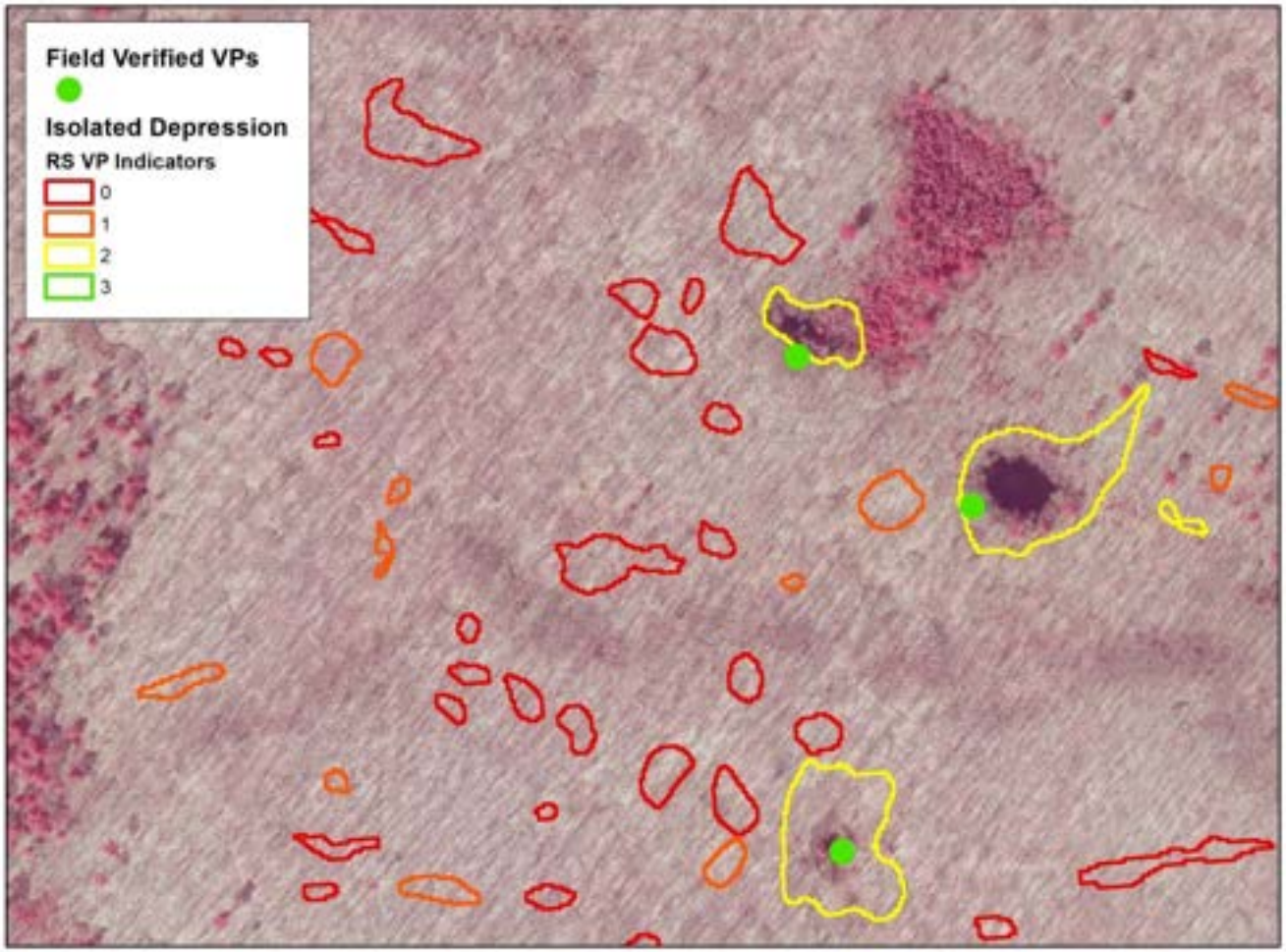
disturbance fairly easily fixed, site in fair to poor condition [ ]

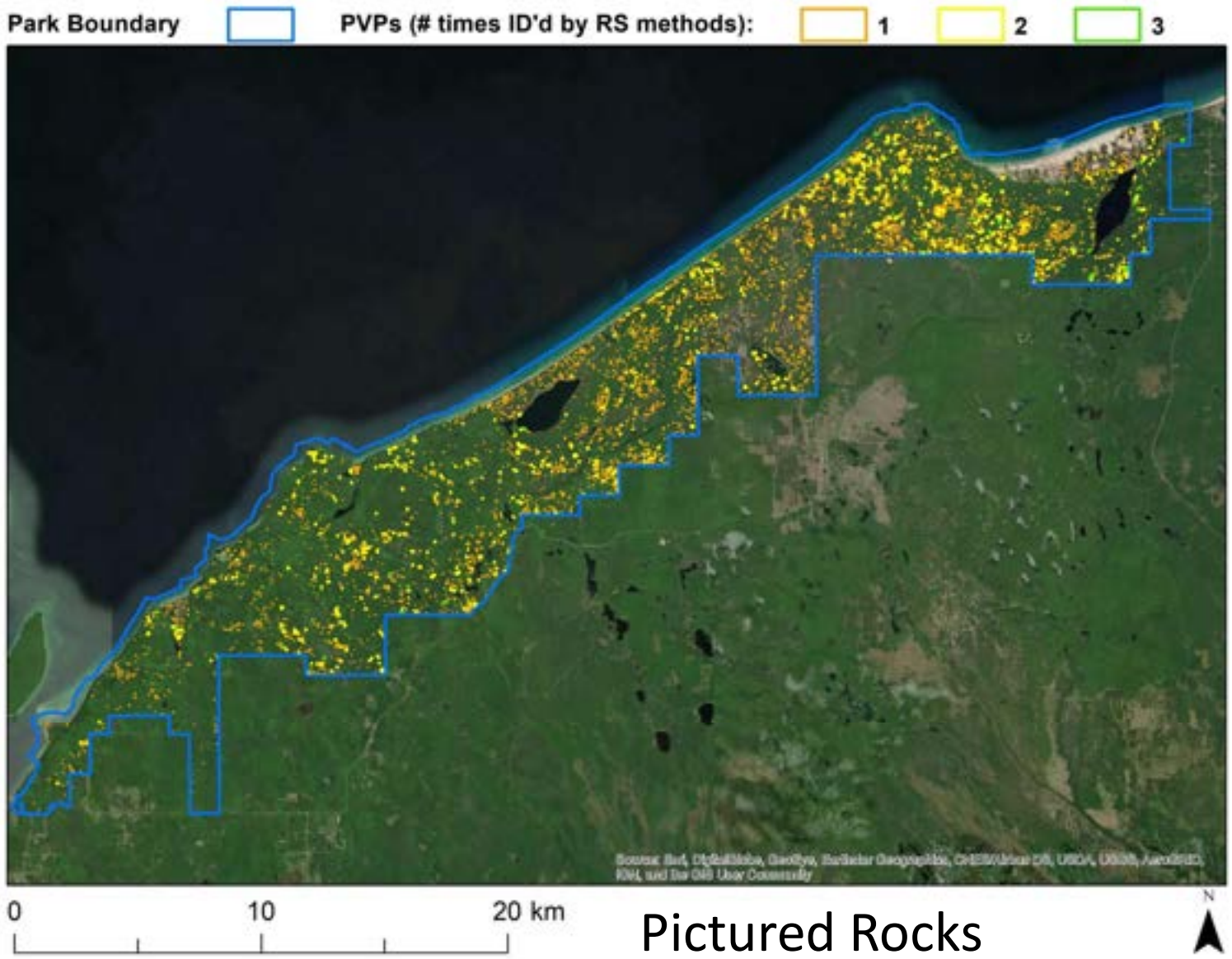
disturbance hard to fix/expensive, site in good condition [ ]

in good to excellent condition, site is very difficult to fix [x]

Draw diagram of pool (include landmarks, location of indicated species, north arrow and area surveyed if entire pool was not surveyed):

Pictured Rocks Example





Pictured Rocks

Park Boundary PVPs (# times ID'd by RS methods): 1 2 3

Sleeping Bear

Accuracy tables for completed parks

Pictured Rocks		Field Classification Yes	Field Classification No
Remote Sensing Classification	Yes	32	7
	No	5	5

Overall Accuracy = 75.5%

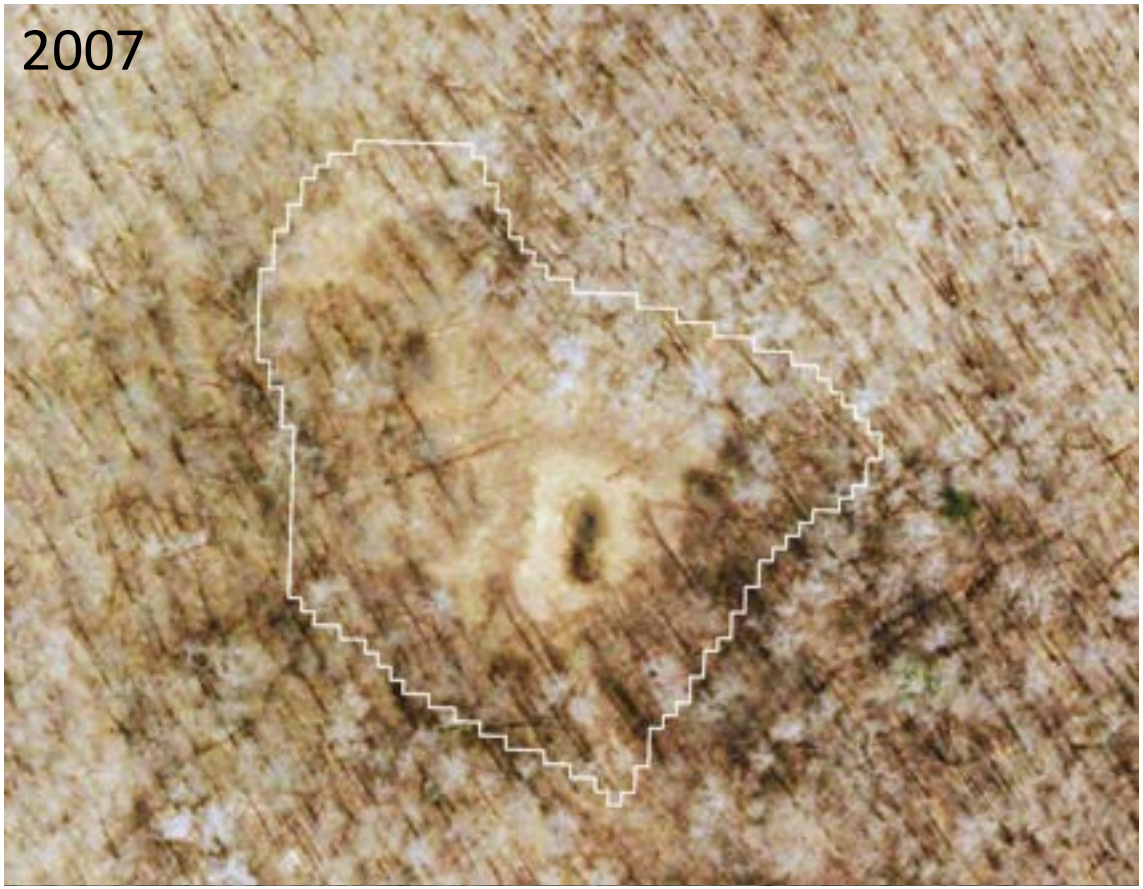
Sleeping Bear		Field Classification Yes	Field Classification No
Remote Sensing Classification	Yes	30	10
	No	1	8

Overall Accuracy = 77.5%

Verified pool water presence

	# Times Water Presence Identified w/ RS			
	1	**2**	**3**	**Total**
Pictured Rocks	10	18	4	**32**
Sleeping Bear	1	23	6	**30**

Interannual Variation in Vernal Pools



Summary and Next Steps

- Multi-source, multi-date remote sensing data is a valuable tool for identifying vernal pools and monitoring inundation in the Great Lakes (~75% overall accuracy) and mapping pool characteristics (cover type and canopy closure). Commission error was greater than omission error.
- More looks at the pools through time would allow us to improve detection of inundation– current data are limited and not consistently collected.
- NASA-ISRO's new L-band SAR, NISAR, is launching in January 2024 and will be unprecedented in the frequency of data collection at high resolution (every 12 days, 10 m resolution)- this exciting dataset will allow us to monitor inundation and hydroperiod of the pools.
- Field monitoring with cameras would allow for validation of remote sensing hydroperiod, wildlife use, phenology, etc.
- Isle Royale (under this project) and Hiawatha National Forest (new funding) will be completed in the coming months.

Thank you - Questions?