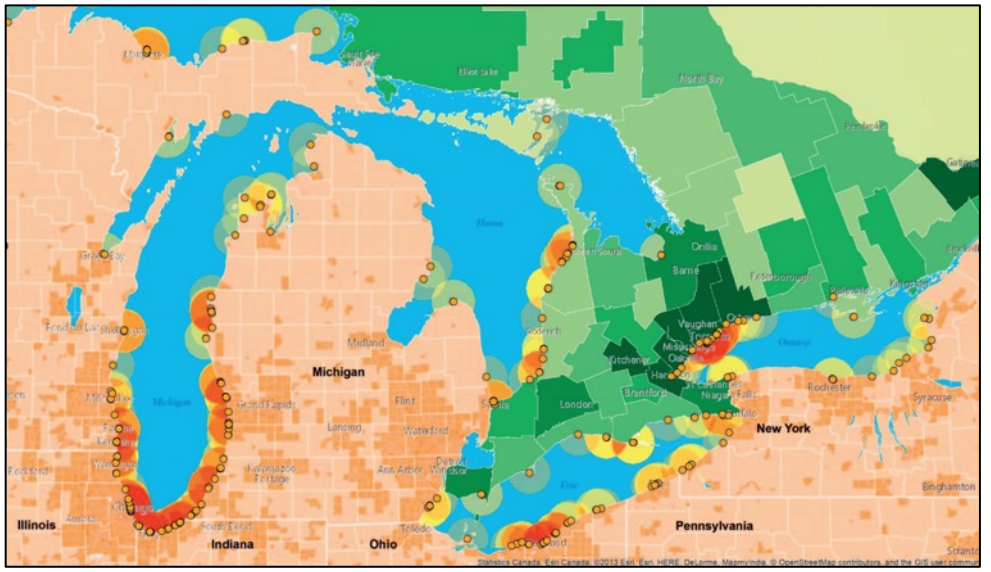
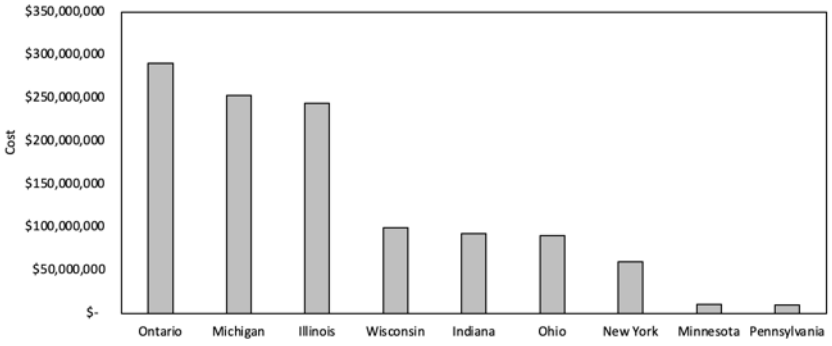
Smart Beach Update

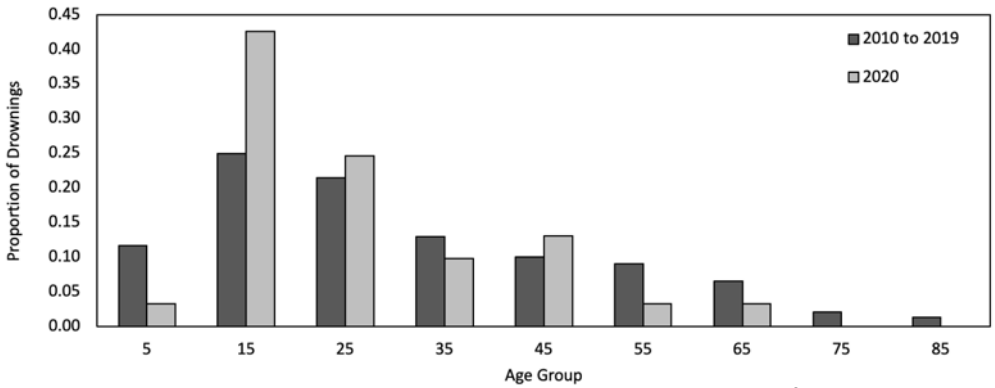
Great Lakes Drowning

- ~50 surf-related drowning fatalities/year
- Majority of drowning fatalities: male and <30
- Ontario has the highest proportion of drownings
- Most attributable to rough surf and rip currents
- Economic burden >$1.1 billion (2010-2020)





Vlodarchyk, B., Olivito, A. and Houser, C., 2019. Spatial and temporal variation of surf drownings in the Great lakes: 2010–17. *Journal of Coastal Research*, *35*(4), pp.794-804.



Houser, C., Arbex, M. and Trudeau, C., 2021. Economic impact of drowning in the Great Lakes Region of North America. *Ocean & Coastal Management*, *212*, p.105847.

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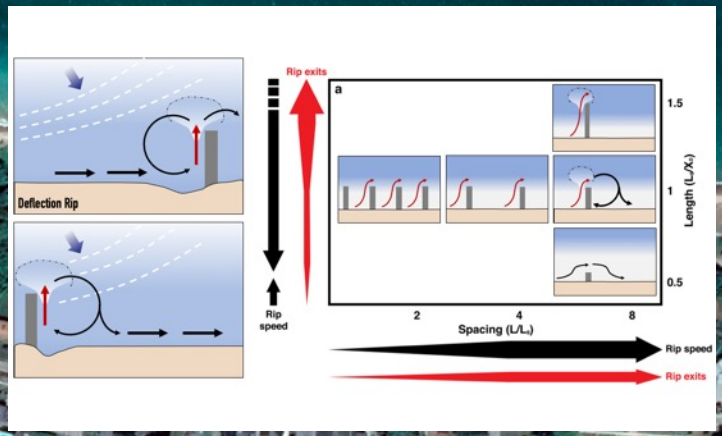
Structural Rips



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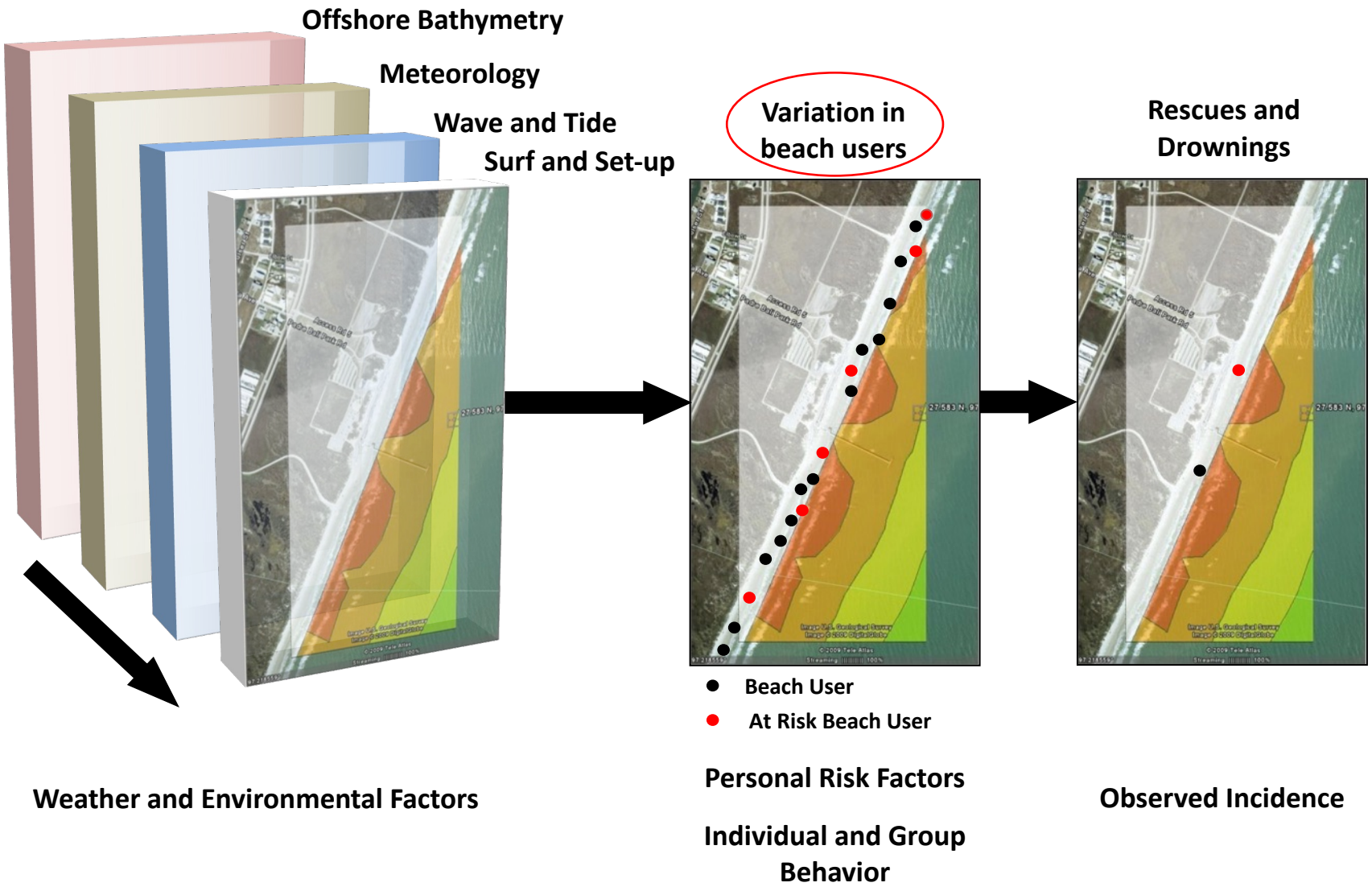

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Lifeguards

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Warning Signs

Beach users tend to ignore signs……

Brannstrom, C., Trimble, S., Santos, A., Brown, H.L. and Houser, C., 2014. Perception of the rip current hazard on Galveston Island and North Padre Island, Texas, USA. *Natural Hazards*, *72*(2), pp.1123-1138.

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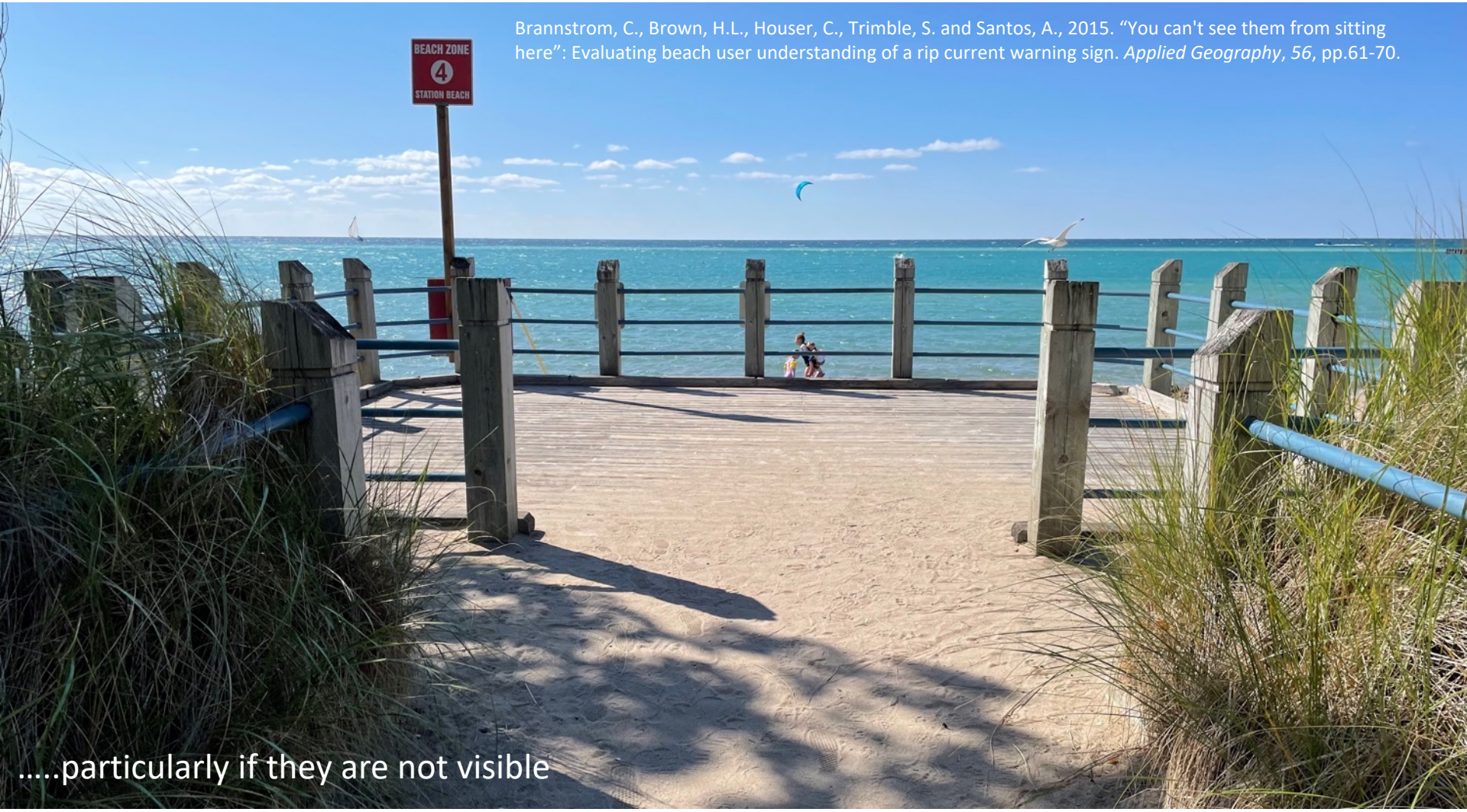

Brannstrom, C., Brown, H.L., Houser, C., Trimble, S. and Santos, A., 2015. "You can't see them from sitting here": Evaluating beach user understanding of a rip current warning sign. *Applied Geography*, *56*, pp.61-70.

.....particularly if they are not visible

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Signs need to be accurate and locally specific

Houser, C., Trimble, S., Brander, R., Brewster, B.C., Dusek, G., Jones, D. and Kuhn, J., 2017. Public perceptions of a rip current hazard education program:"Break the Grip of the Rip!". *Natural hazards and earth system sciences*, *17*(7), pp.1003-1024.

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Warning Flags

Arozarena, I., Houser, C., Echeverria, A.G. and Brannstrom, C., 2015. The rip current hazard in Costa Rica. *Natural Hazards*, *77*(2), pp.753-768.

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What Flag Color?

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People will be cautious if the water looks dangerous, but can be influenced by others to enter the water

Houser, C., Lehner, J., Cherry, N. and Wernette, P., 2019. Machine learning analysis of lifeguard flag decisions and recorded rescues. *Natural Hazards and Earth System Sciences*, *19*(11), pp.2541-2549.

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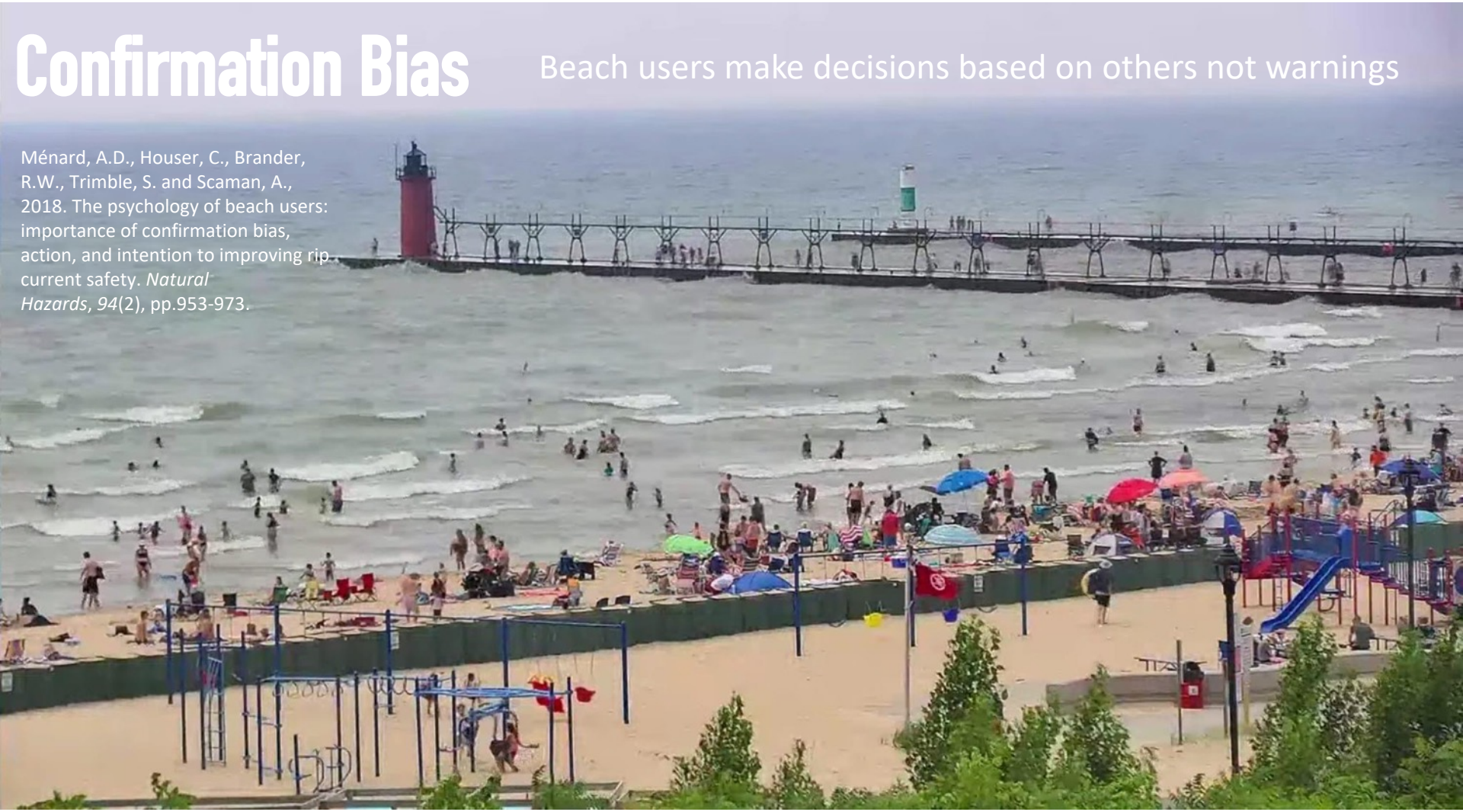
Site-specific Warnings

People will ignore warnings if they believe that the hazard assessment is too restrictive or not representative

Warnings need to be dynamic and local and instill confidence that they are based on a real threat to their safety

Confirmation Bias

Beach users make decisions based on others not warnings



Ménard, A.D., Houser, C., Brander, R.W., Trimble, S. and Scaman, A., 2018. The psychology of beach users: importance of confirmation bias, action, and intention to improving rip current safety. *Natural Hazards*, *94*(2), pp.953-973.

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Beach users assume that access means that the beach must be safe

Trimble, S. and Houser, C., 2018. Seawalls and signage: How beach access management affects rip current safety. In *Beach management tools-concepts, methodologies and case studies* (pp. 497-524). Springer, Cham.

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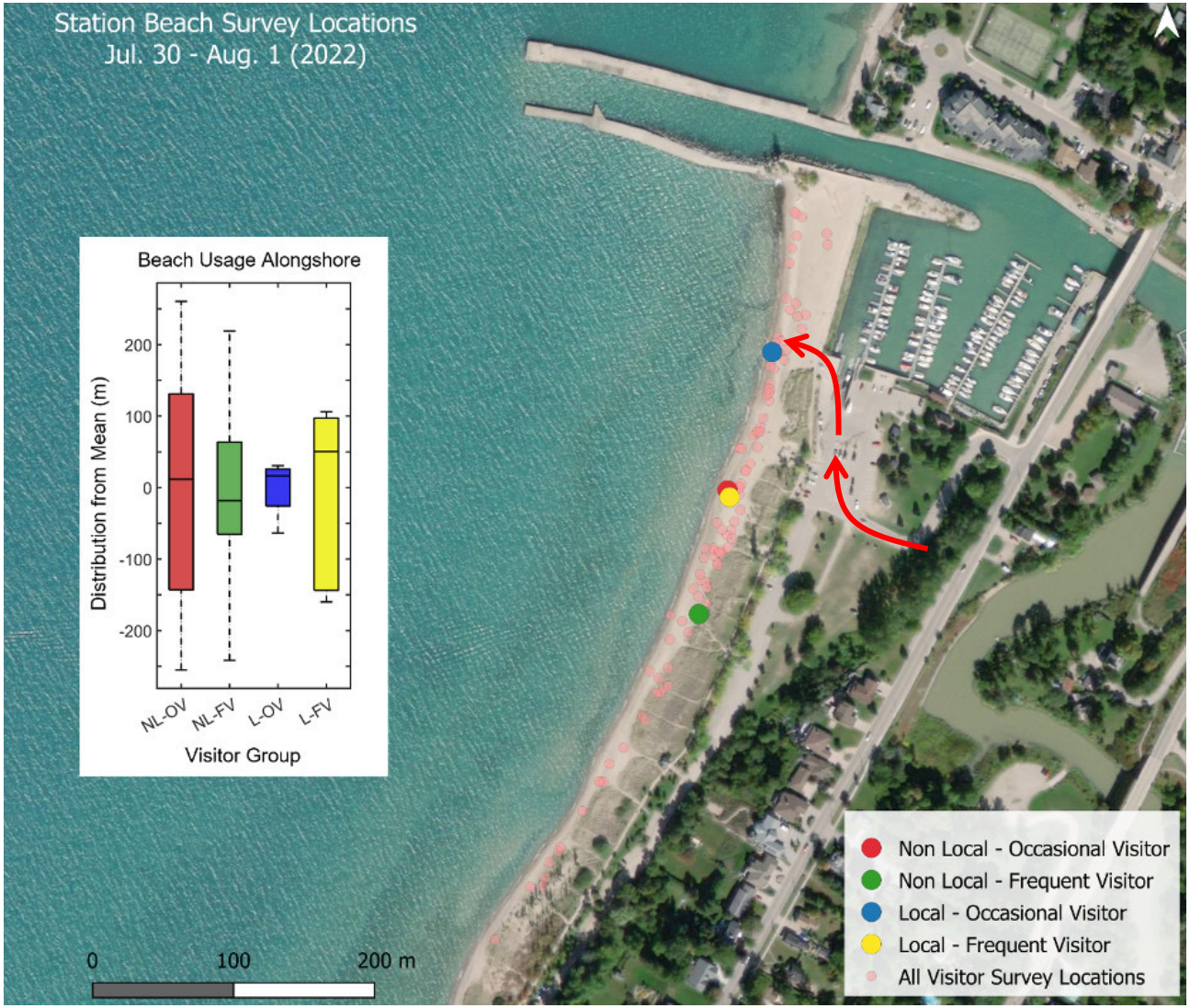

Houser, C., and Smith, A. (*Accepted with Minor Revisions*). Short Communication: Perception of beach safety at a destination beach on the Great Lakes. Submitted to Canadian Geographies. September 2023.

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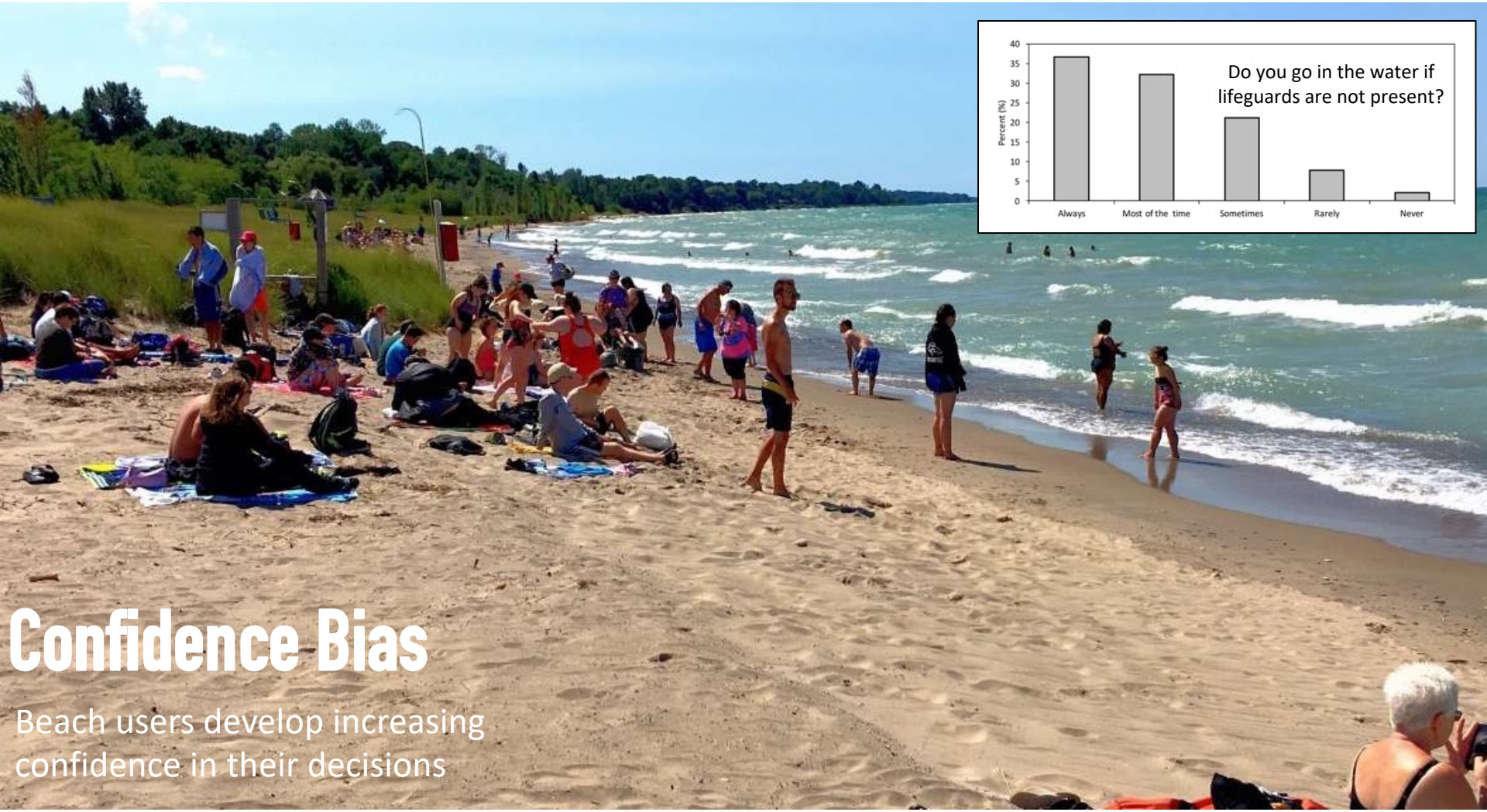

Confidence Bias

Beach users develop increasing confidence in their decisions

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Design Nudges: Use positive reinforcement and indirect suggestions to try to achieve non-forced compliance and influence the motives, incentives and decision making of groups and individuals

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Beach Safety Issues

- Combination of bathymetric and structural rips plus strong surf
- Seasonal and storm-dependent hazard
- Spatially variable hazard on same beach
- Inconsistent and invisible signage
- Access guides behavior towards no swim zone
- Safety is dependent on social norms and design nudges

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To develop, implement and test an **integrated sensor network** to provide a real-time and **locally calibrated risk and hazard warning** system for beach users and local authorities that in **guides the behavior of beach users** through a dynamic warning system.

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Integrated Sensor Network

Objective 1

WebCAT Cameras

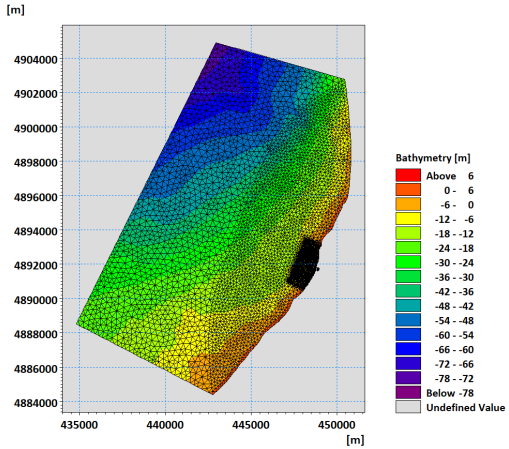
- Anonymized beach user counts
- Spatial variation of surf
- Automatic rip current detection
- Beach erosion monitoring

Local Meteorological Station

Real-time Wave Sensors

Wave and Current Model

Objective 2



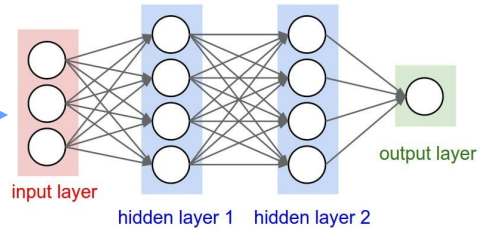
Field validated high-resolution wave and current model using Mike21/3 Software

Summer 2022 & 2023 conditions

Past drowning and rescue events

Extended Wave Model

Objective 3



Artificial Neural Network (ANN) model extension of wave and current model to all possible forcing conditions

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Beach User Perception

Objective 4 & 6

Crowd-sourced assessment of surf conditions and swimming conditions

Beach user perception of warning system and incentives to safe behavior

Dynamic Flag System

Objective 4

Locally-calibrated and evidence-based flag or light system that is spatially or temporally variable based on predicted and observed wave and current conditions

Beach User App & ?

Objectives 5 & 6

Real-time and forecast surf hazard at Station Beach

Dynamic and personalized warning based on beach user location

Incentives to safe behavior

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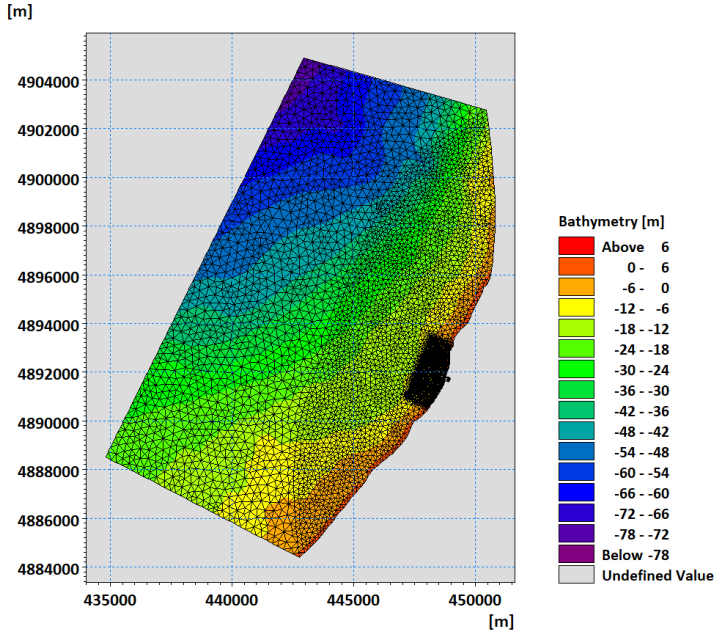
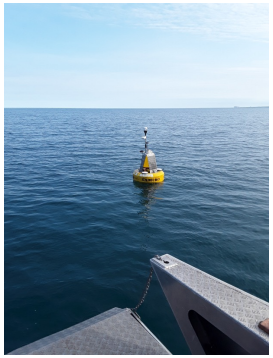
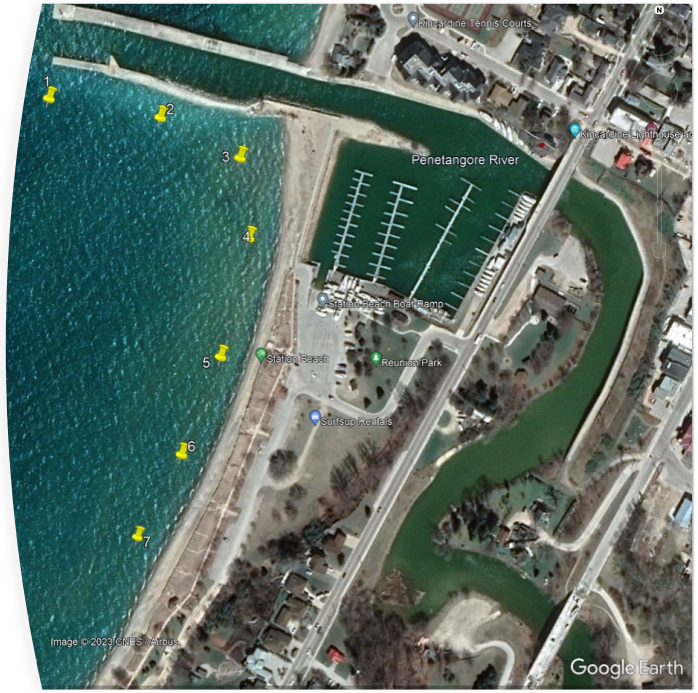
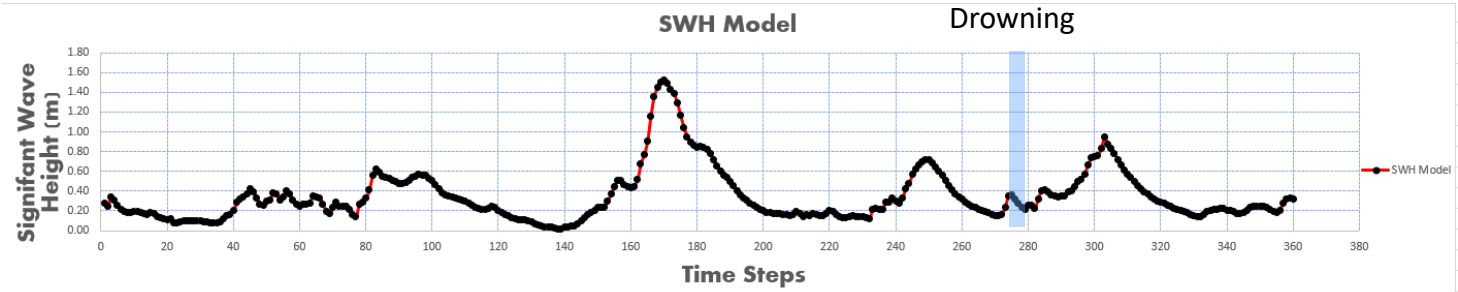
Wave Modeling







Wave height of ~0.40 m



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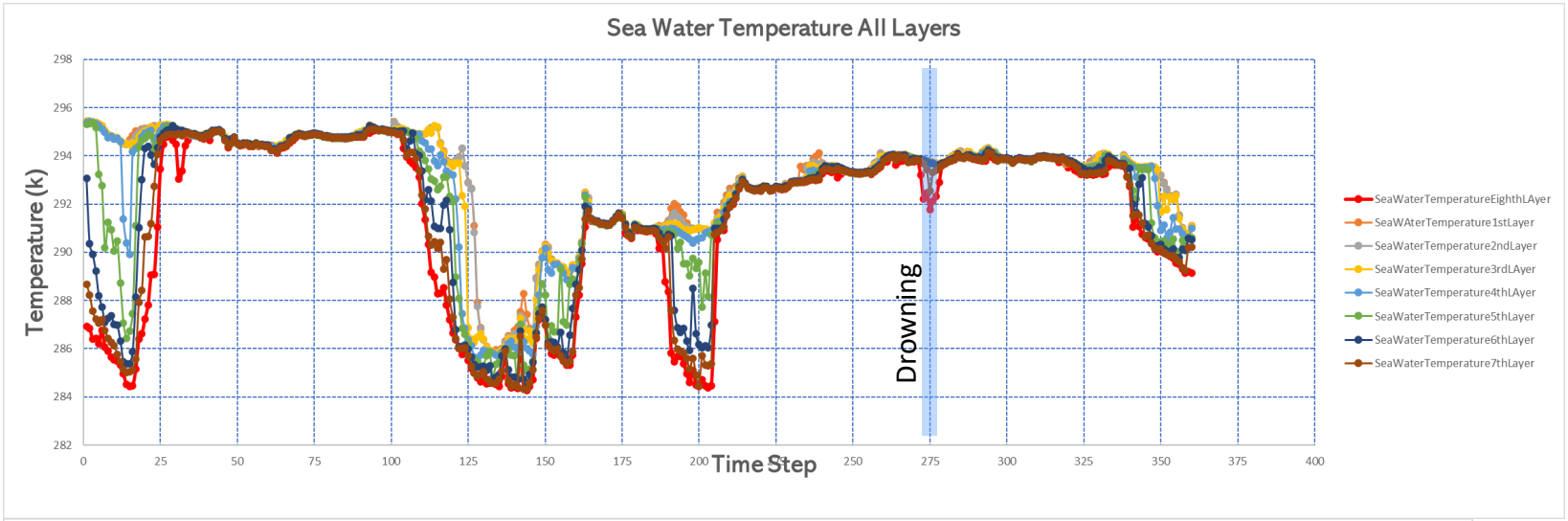
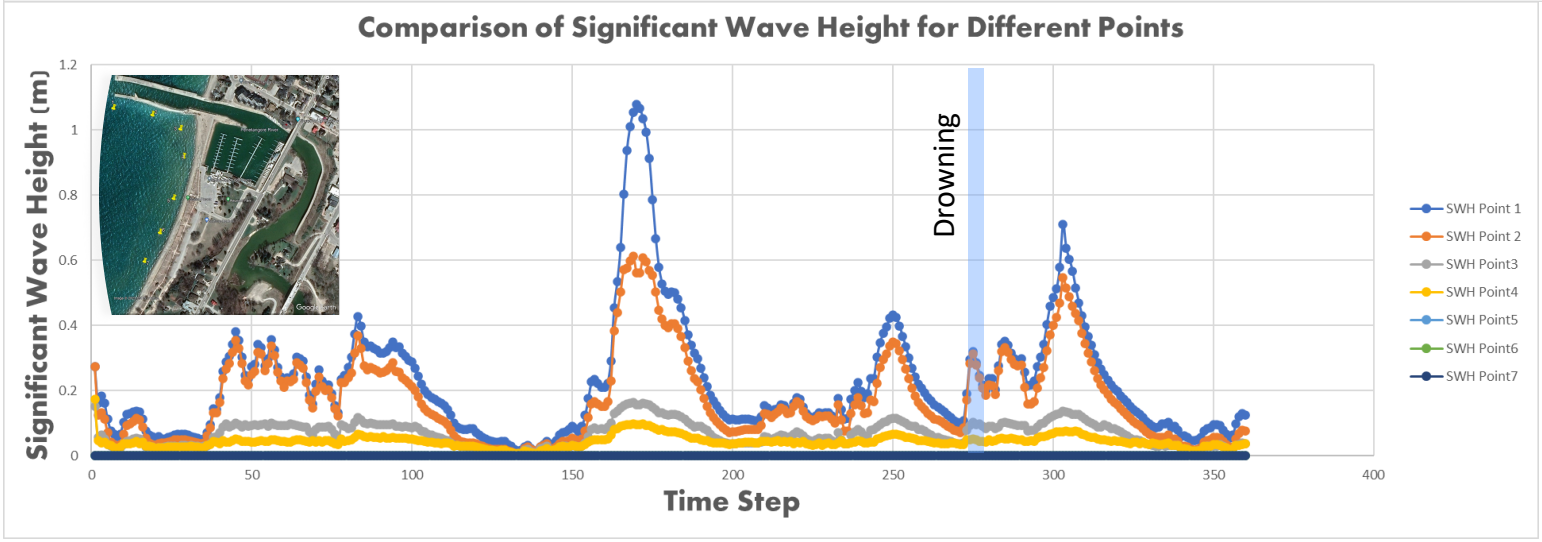


Minor Upwelling



Along jetty wave height of ~0.40-0.15 m

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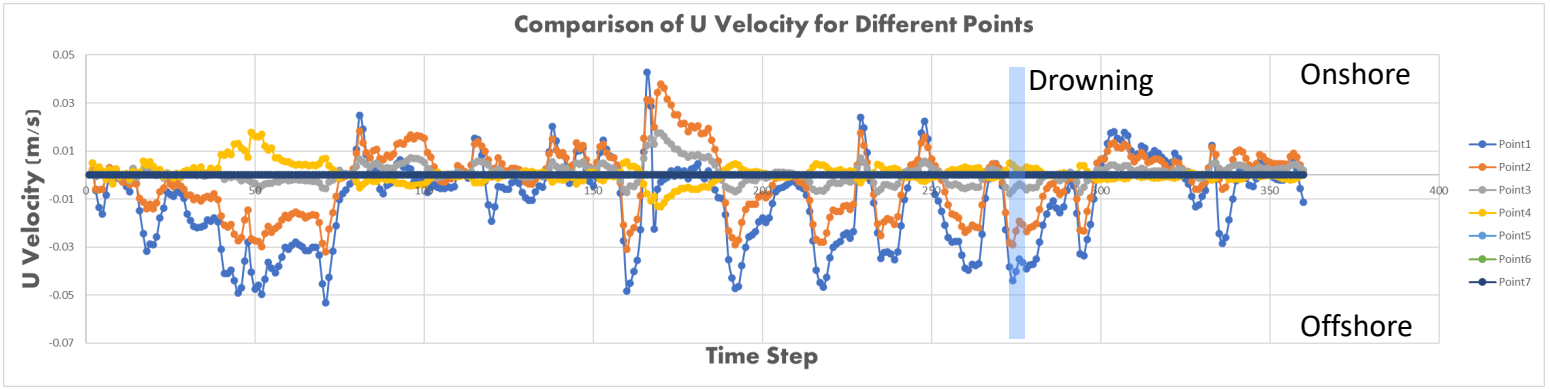

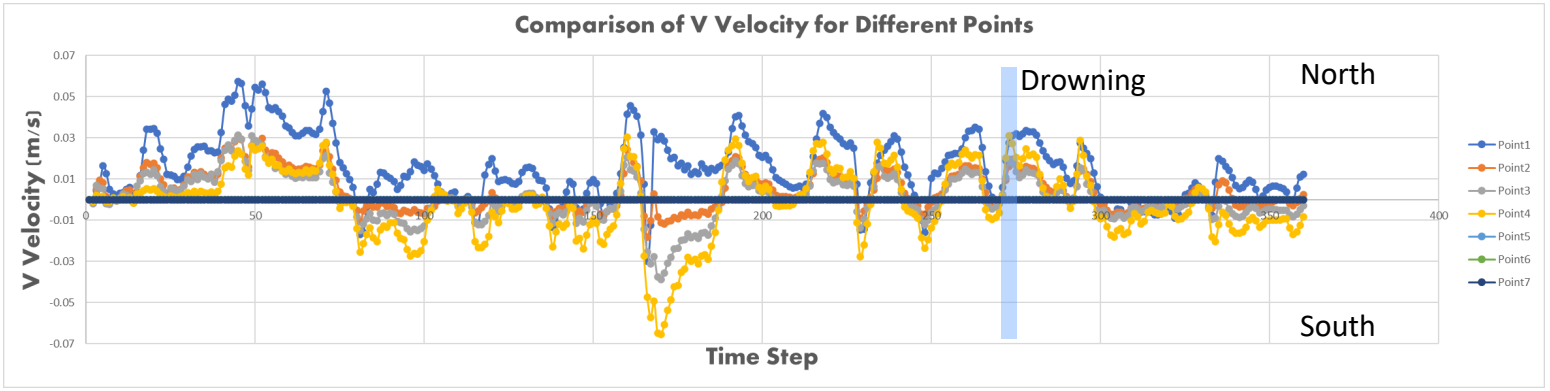

Weak to moderate offshore current along the jetty at the time of the drowning

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Primary Issues

- Access guides users to the jetty
- Access along jetty
- Inadequate signage
- Upwelling, waves and rip on date
- No lifeguards
- Personal factors

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Representative Conditions

What flag should be flying on this day?

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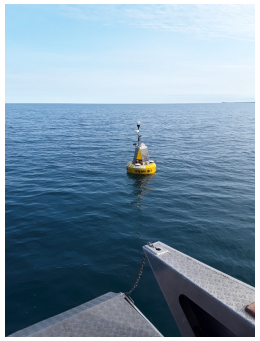
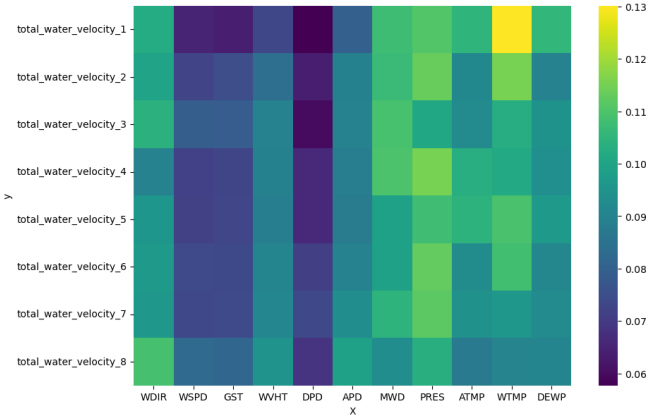
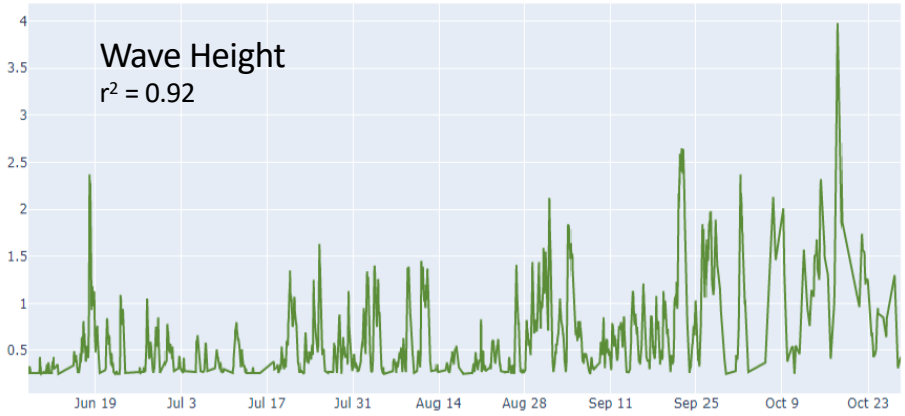
Predict nearshore surf conditions from buoy



Random Forest

- Following initial model selection and hyperparameter testing, a RF ML model provided the most accurate results.
- Feature importance analysis led to further model optimization
- Accurate predictions of surf conditions, including wave height (r^2=0.92) and water temperatures (r^2=0.99).





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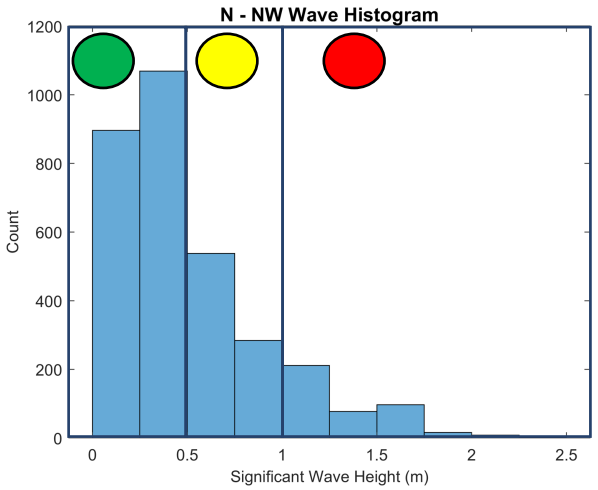

Predict wave heights and surf hazards from cameras

- Images were classified based on expected swim hazards, including green (<50 cm), .yellow (< 1m), and red (> 1m)
- 90% accuracy of RF model compared to nearshore waves
- Future work will implement expert lifeguard knowledge to provide a more representative green – red gradient

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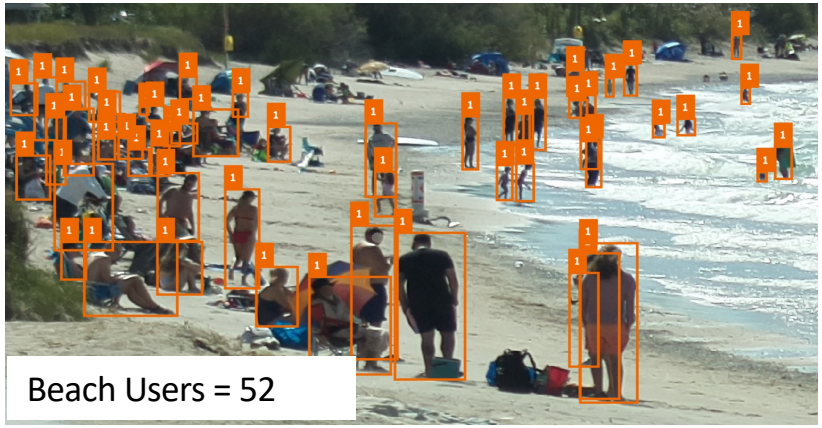
Anonymization

Distribution of Beach Users

- Each image collected is anonymized in pre-processing
- >90% accuracy with 50 or less beach users
- Image segmentation allows for counts at ZOI (water – beach)
- Density mapping during high usage (N > 50) is planned



Beach Users = 52

Segmentation

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Next Steps: Smart Beach

- Modeling of weather and offshore wave data to inshore wave and current conditions
- Predictive (ML) model of wave and current conditions based on all possible combinations of wind and wave conditions (with Georgian College)
- Crowd-sourced assessment of inshore wave and current conditions in support of warning system
- Implementation and testing of warning system (summer 2024) and testing of warning and prediction platform (with Georgian College)

Smart Beach Update