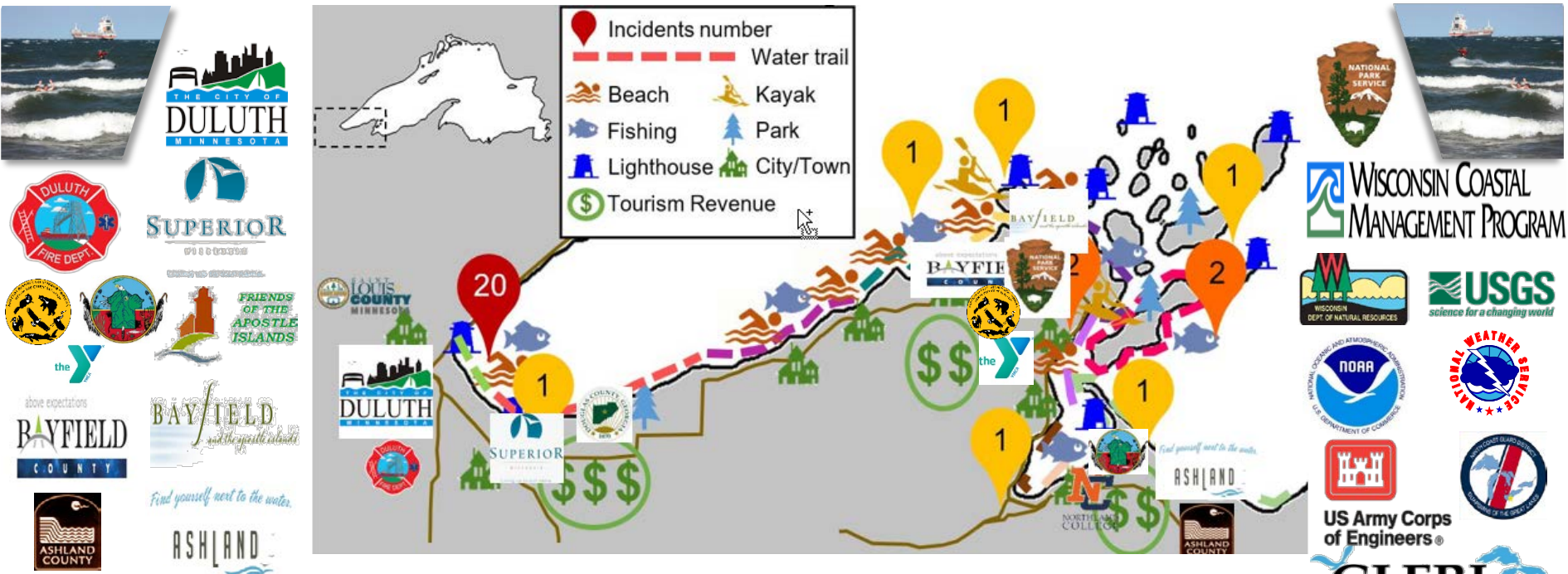


# Characterizing & Forecasting **Dangerous Currents** on the South Shore of Lake Superior in Minnesota and Wisconsin



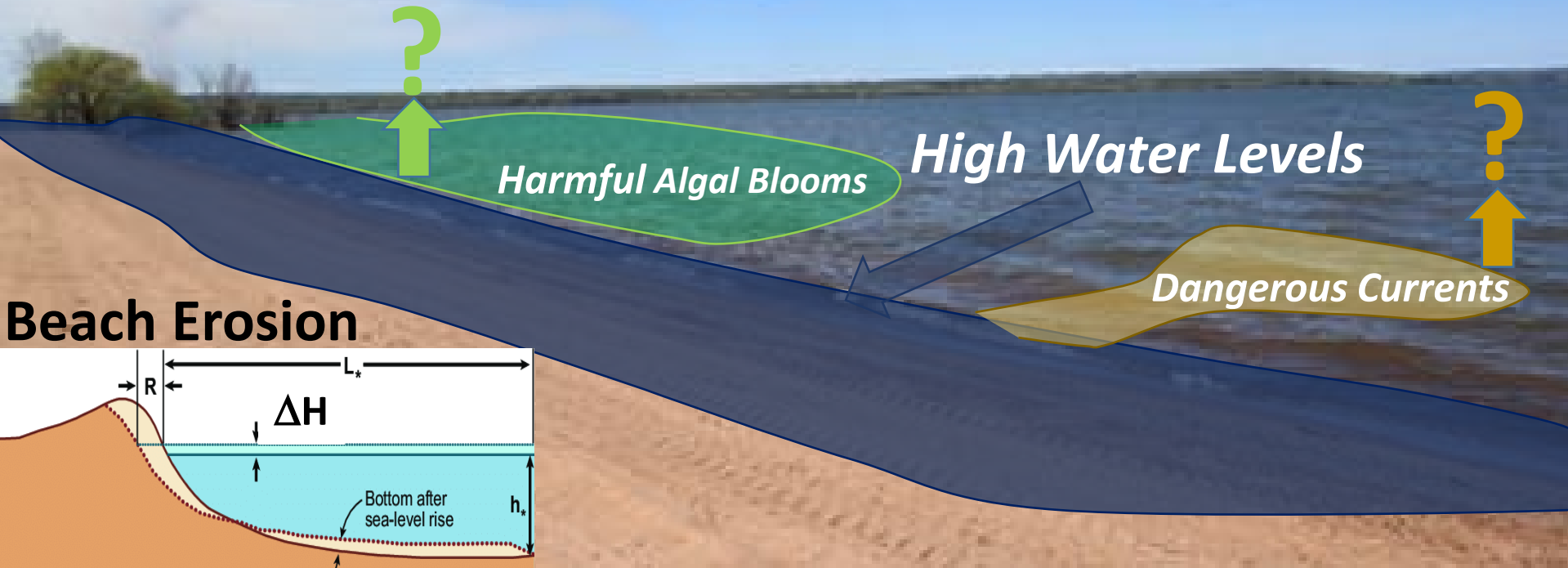
## Wisconsin Coastal Beaches Working Group

October 29-30, Ashland, WI

Chin Wu & Yuli Liu



# Wisconsin Coastal Beaches Working Group



Convene local, state, federal, university and non-profit partners involved in beach research, management, education and communication for information sharing, collaboration and networking to hear reports from Wisconsin's beach partners on **restoration projects** and **beach issues (water quality and safety & hazards)**

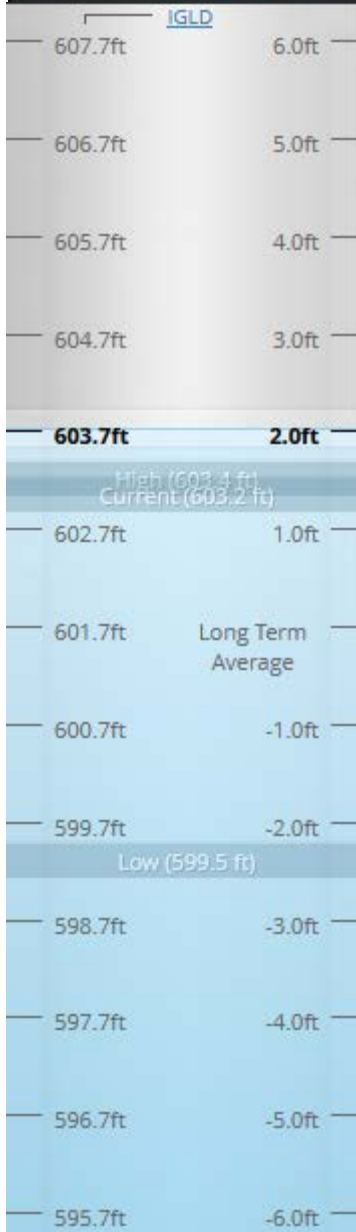






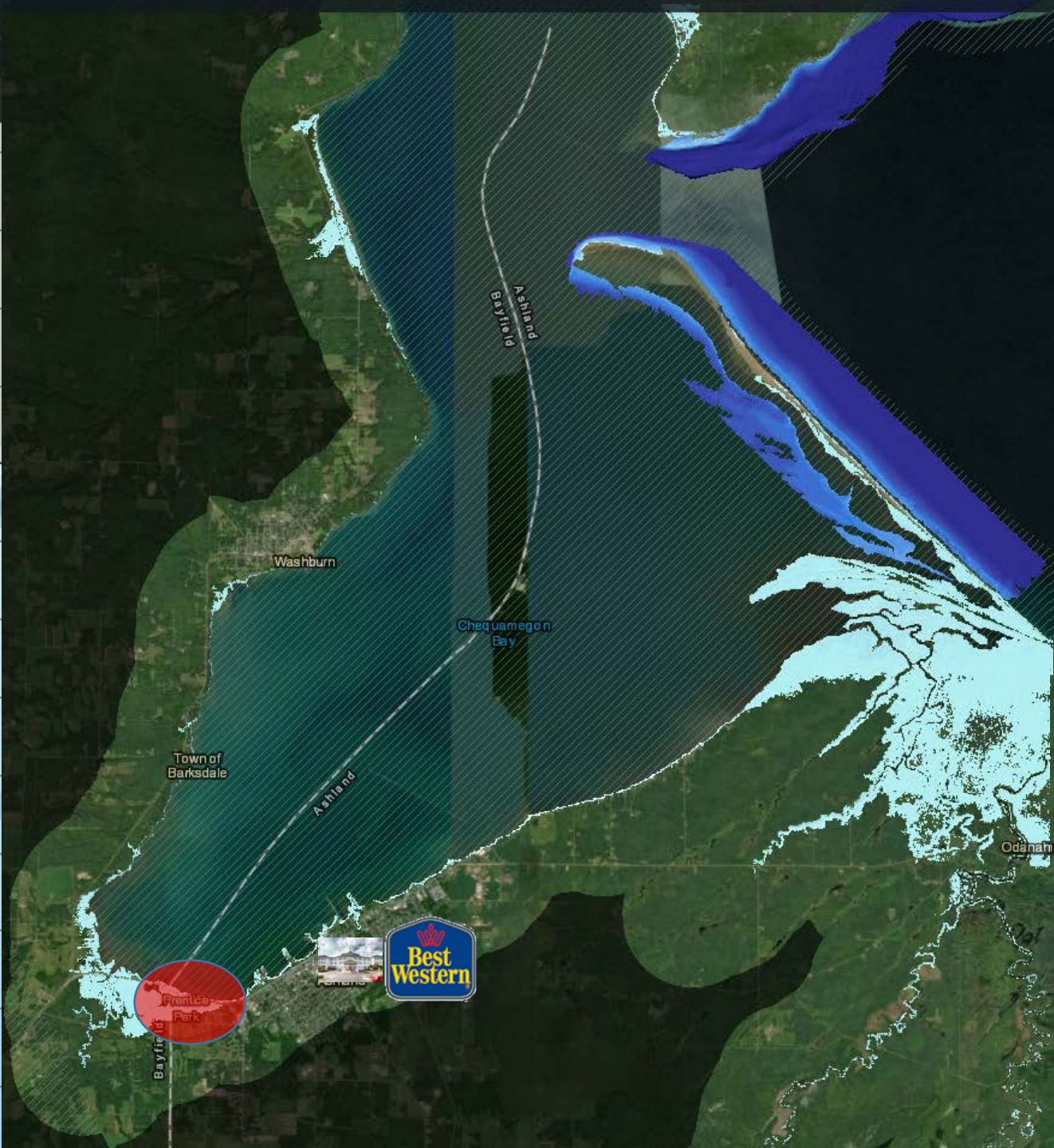
# Lake Level Viewer

## Lake Superior Water Level



2 ft

1 ft

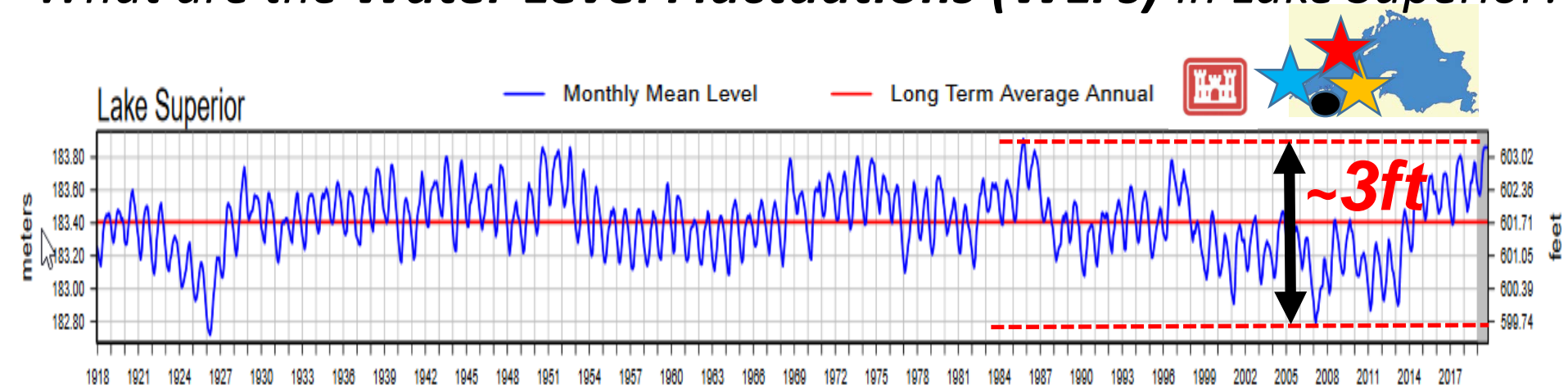




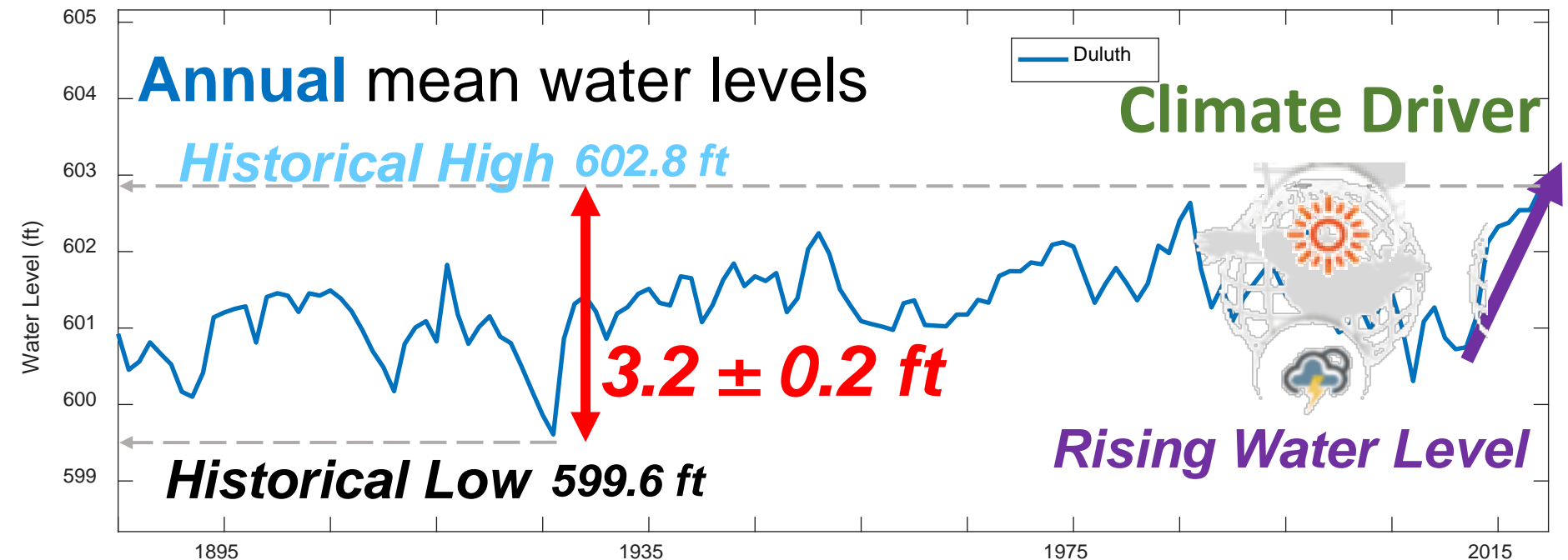
# Maslowski Beach, Ashland



- What are the **Water Level Fluctuations (WLFs)** in Lake Superior?

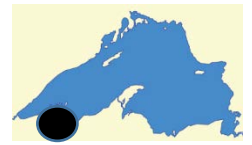


- Are the **WLFs** in Lake Superior representative for **Chequamegon Bay**?





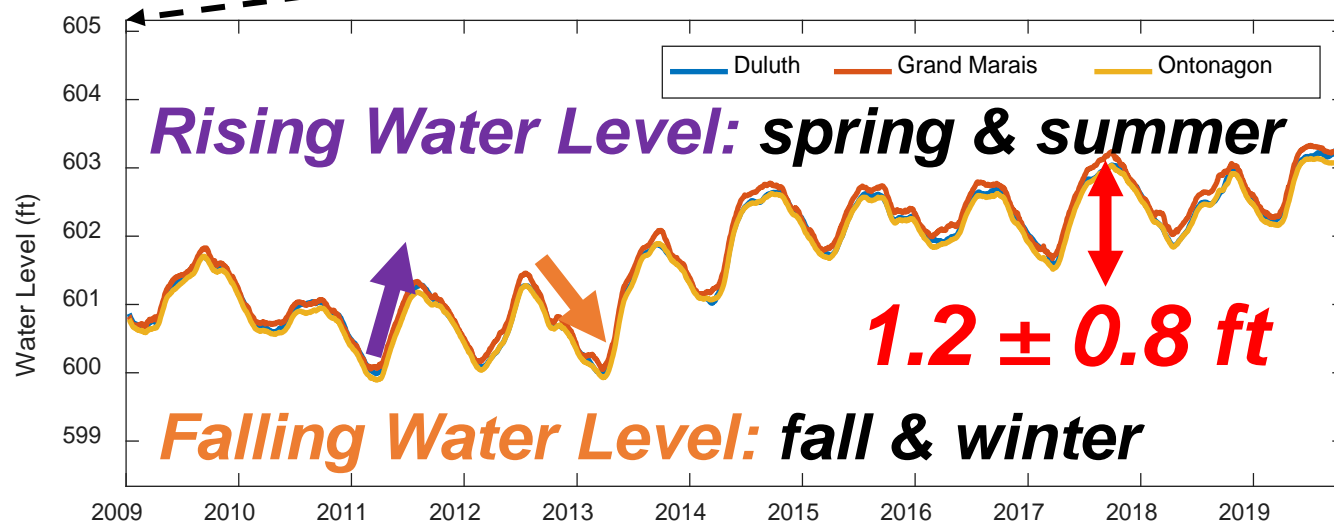
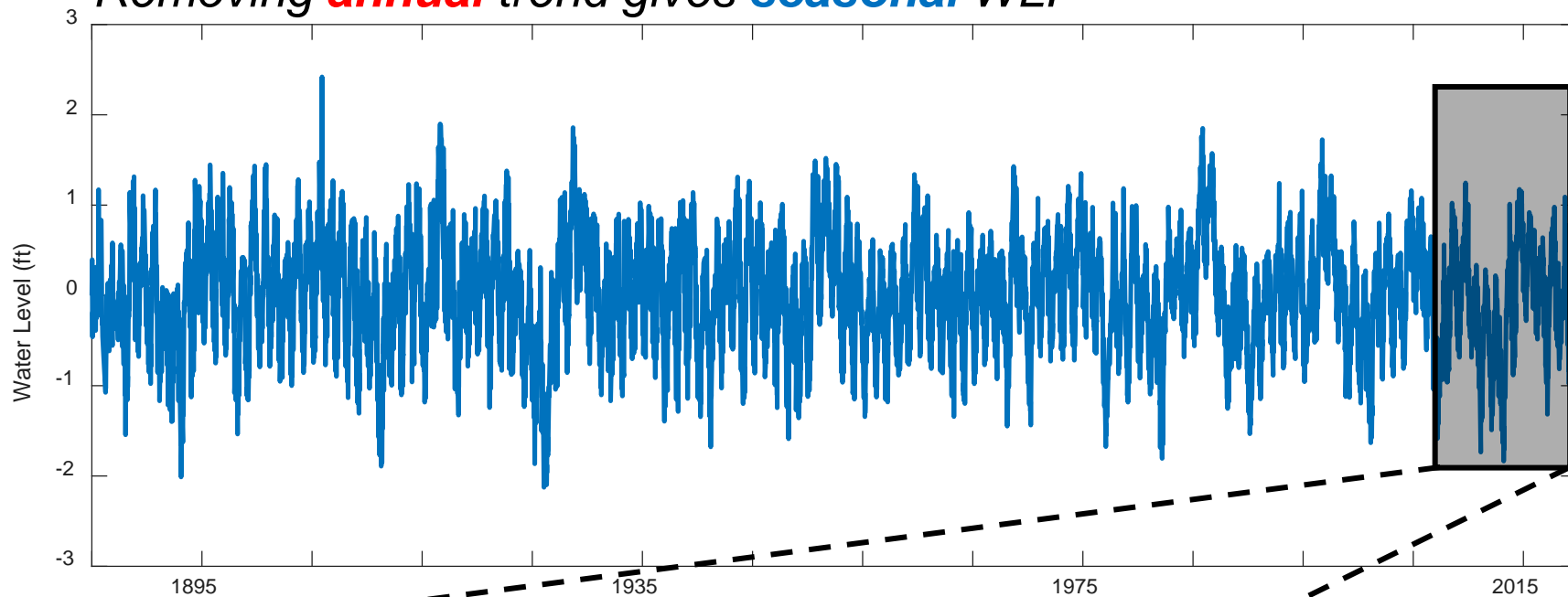
- *Should we be concerned about “seasonal” WLFs?*



• Should we be concerned about “seasonal” WLFs?



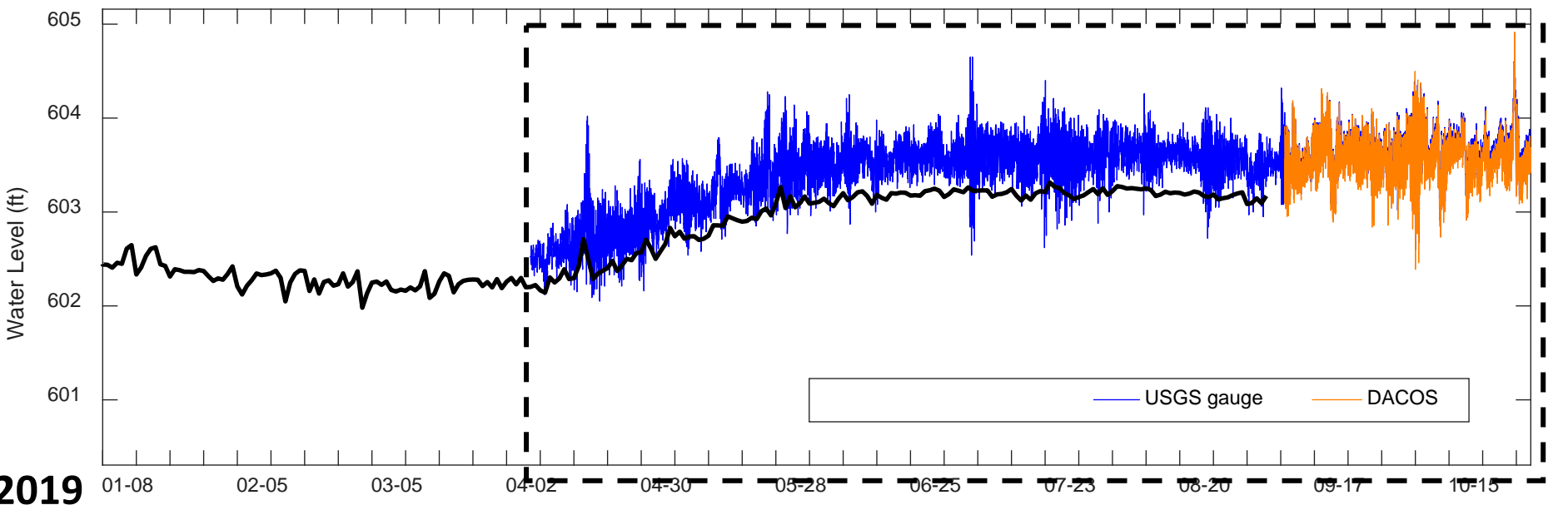
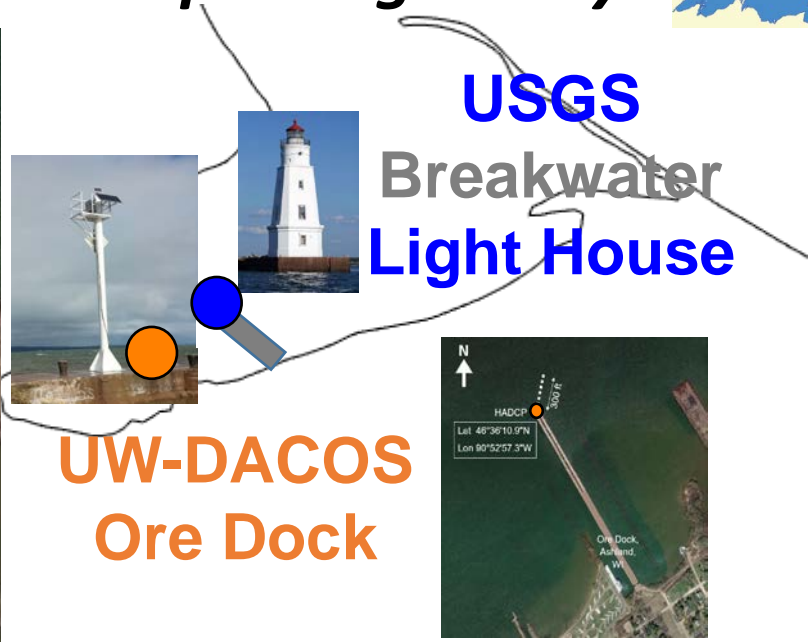
Removing **annual** trend gives **seasonal** WLF



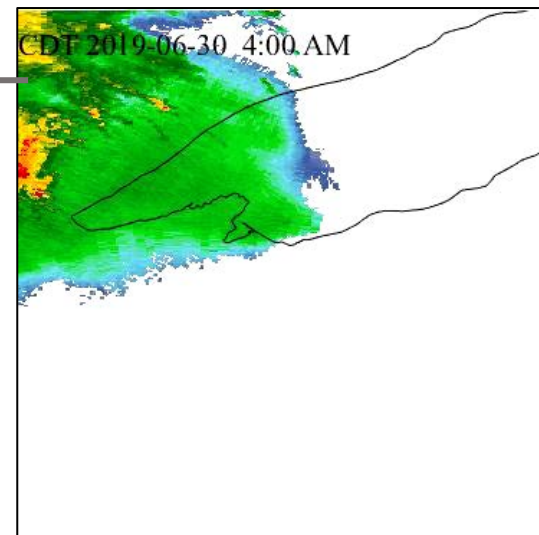
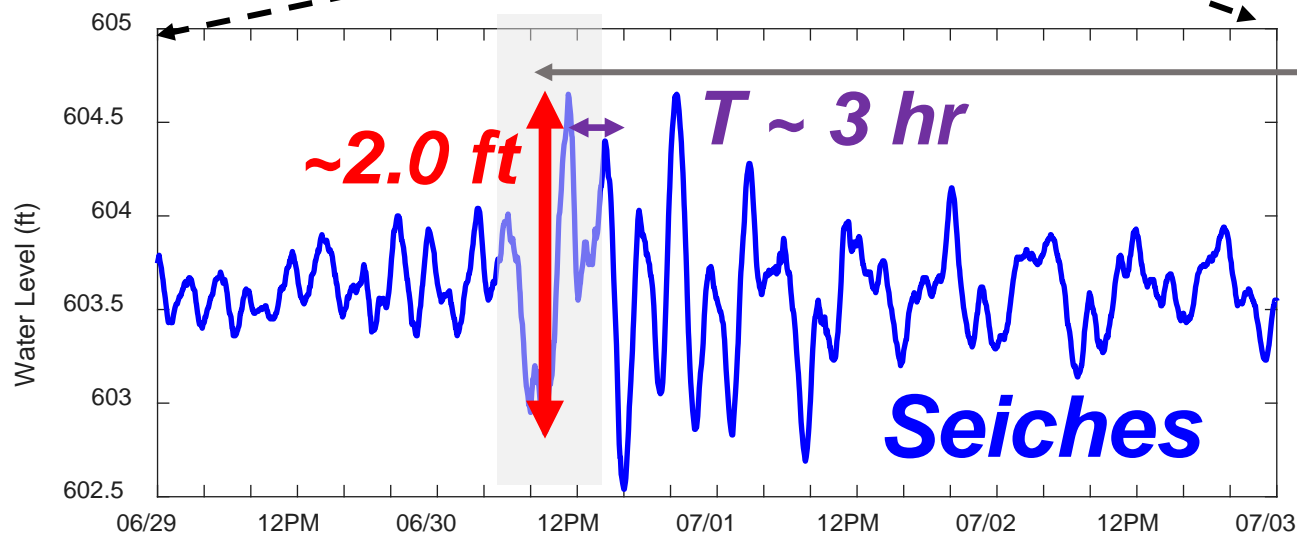
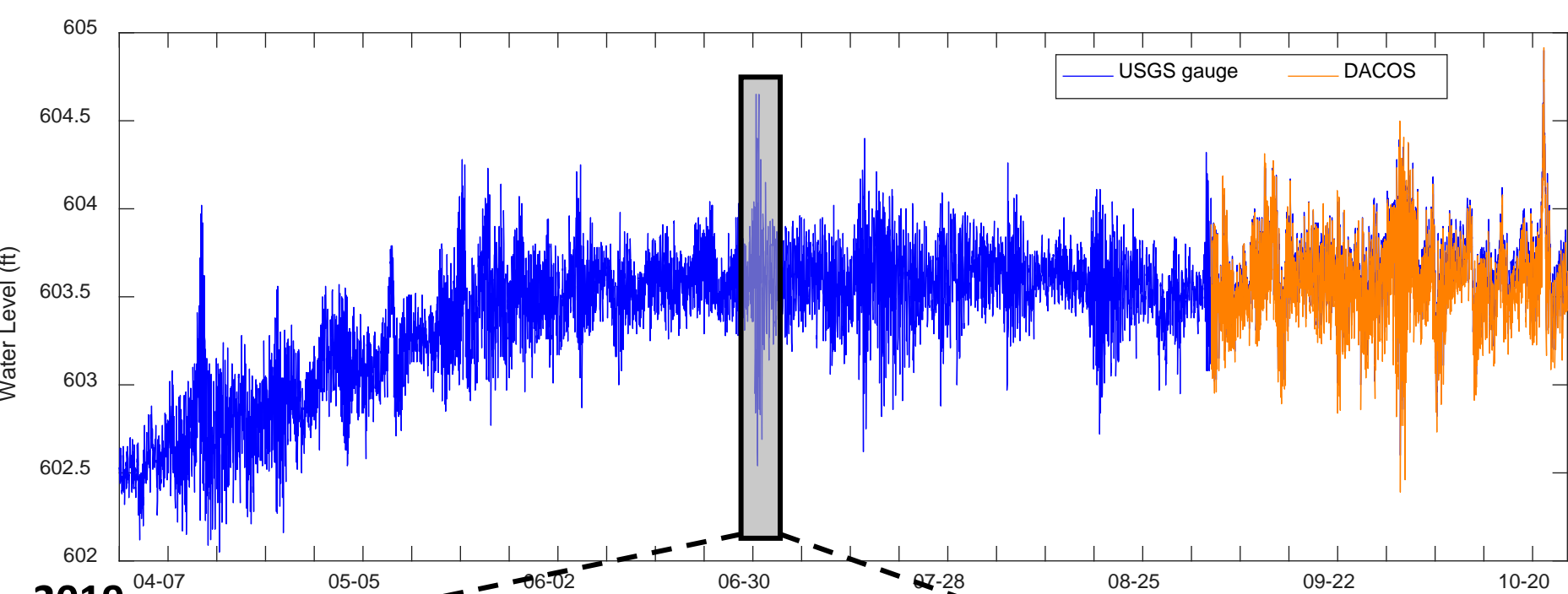
**Hydrological Driver**



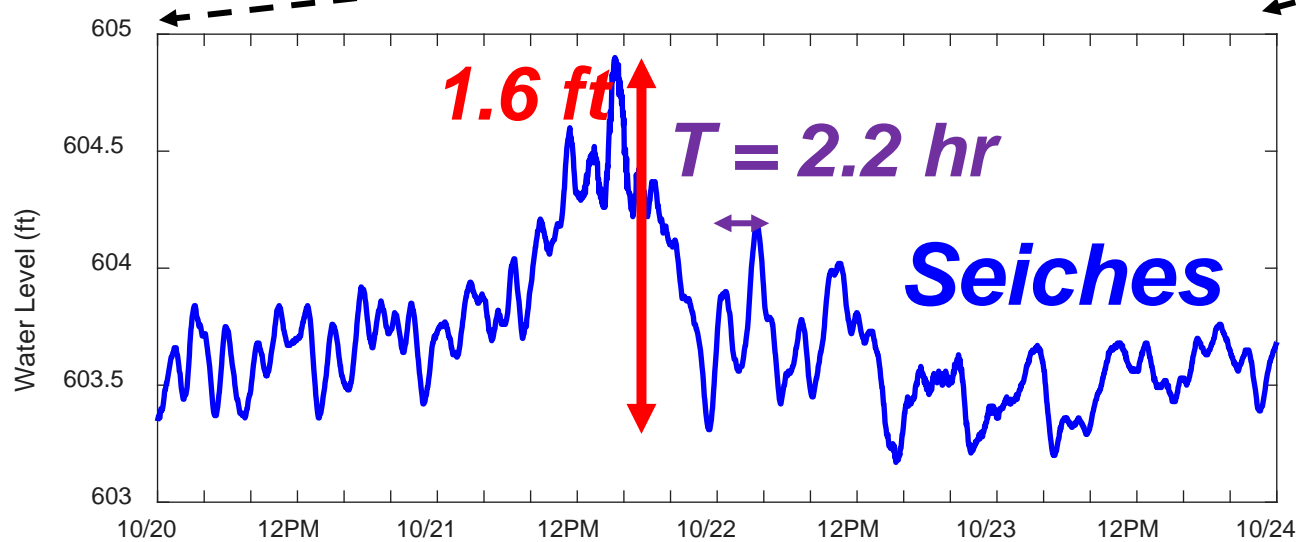
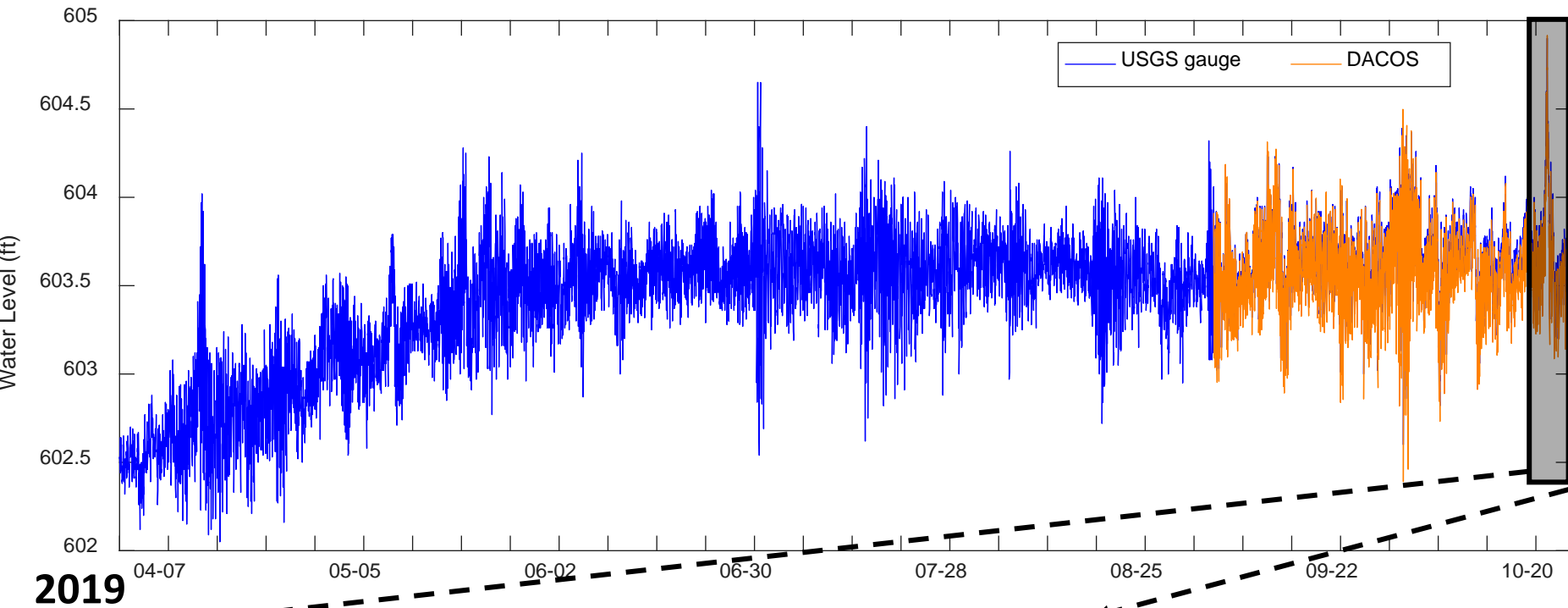
• Are *short-term WLFs* significant in *Chequamegon Bay*?



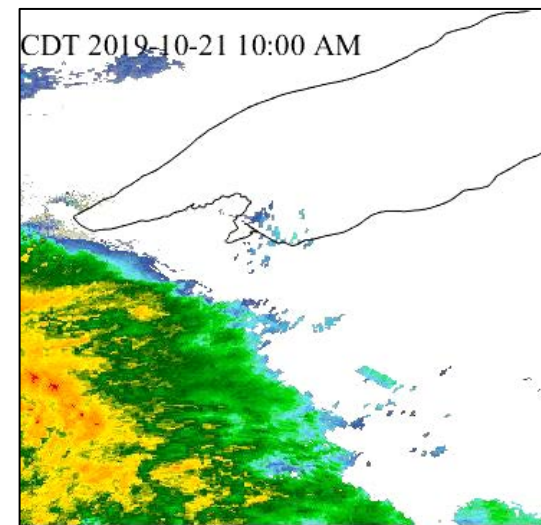




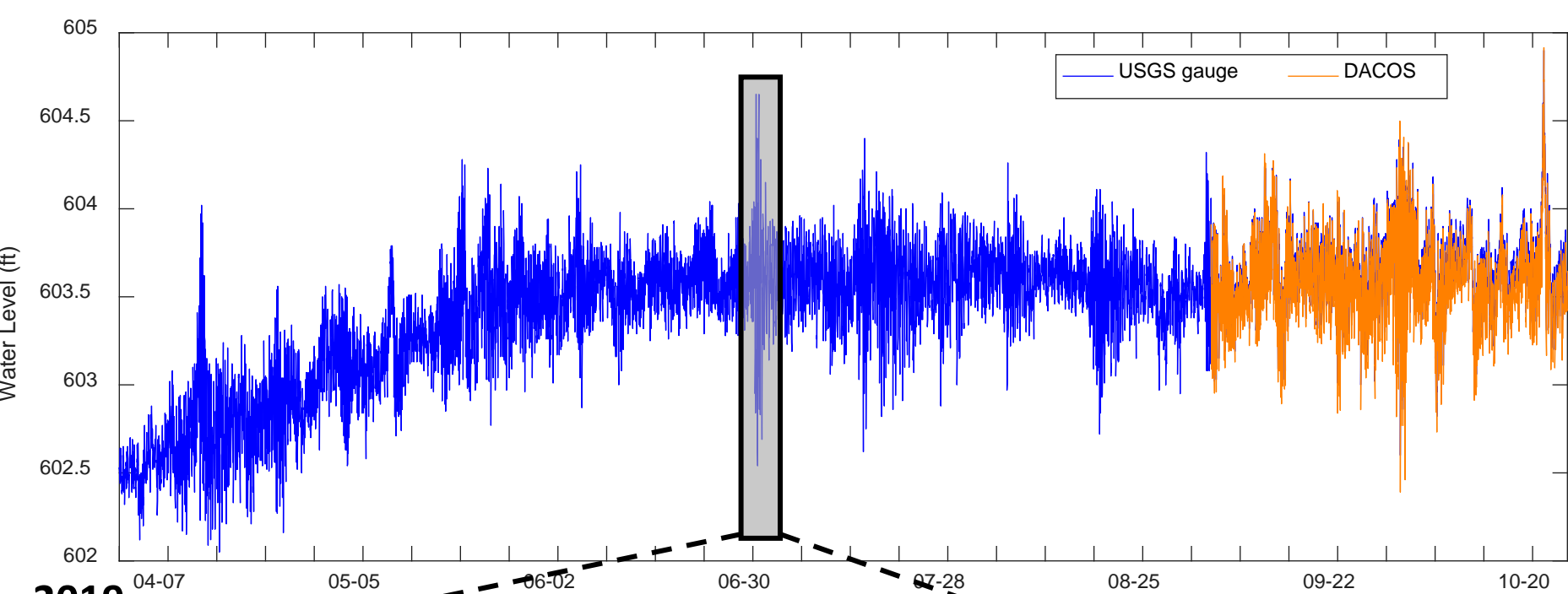
**Moving Storm**



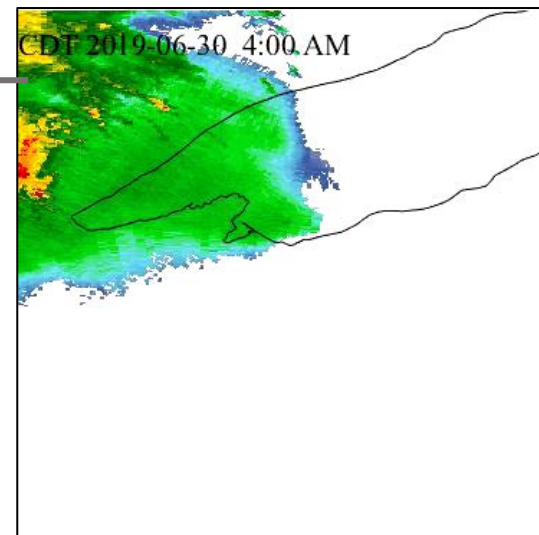
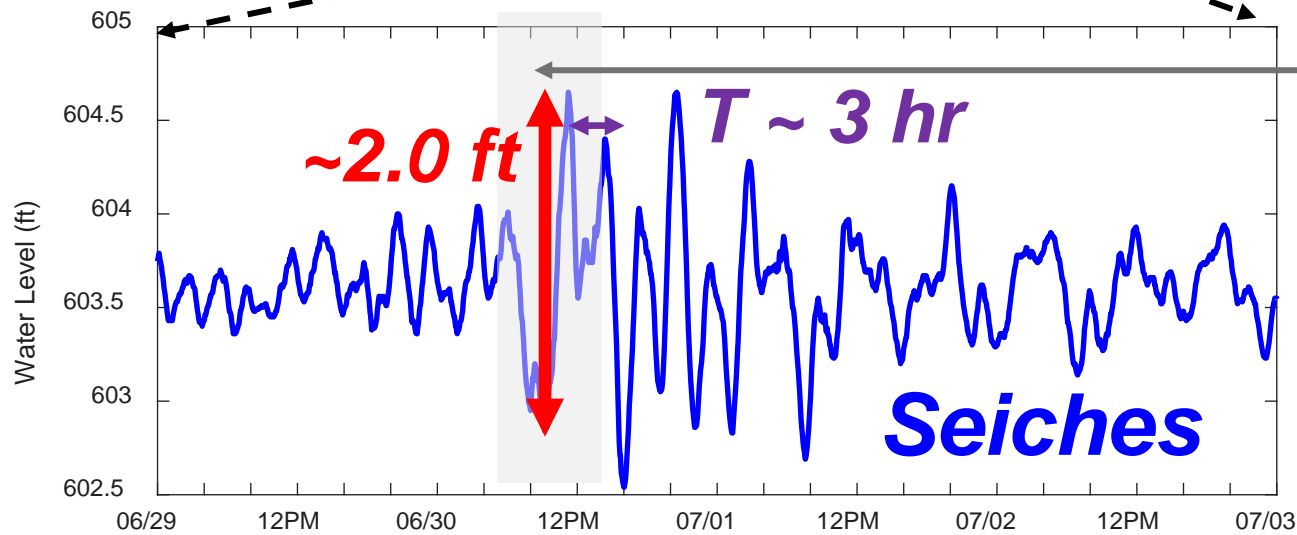
**Weather Driver**



**Moving Storm**



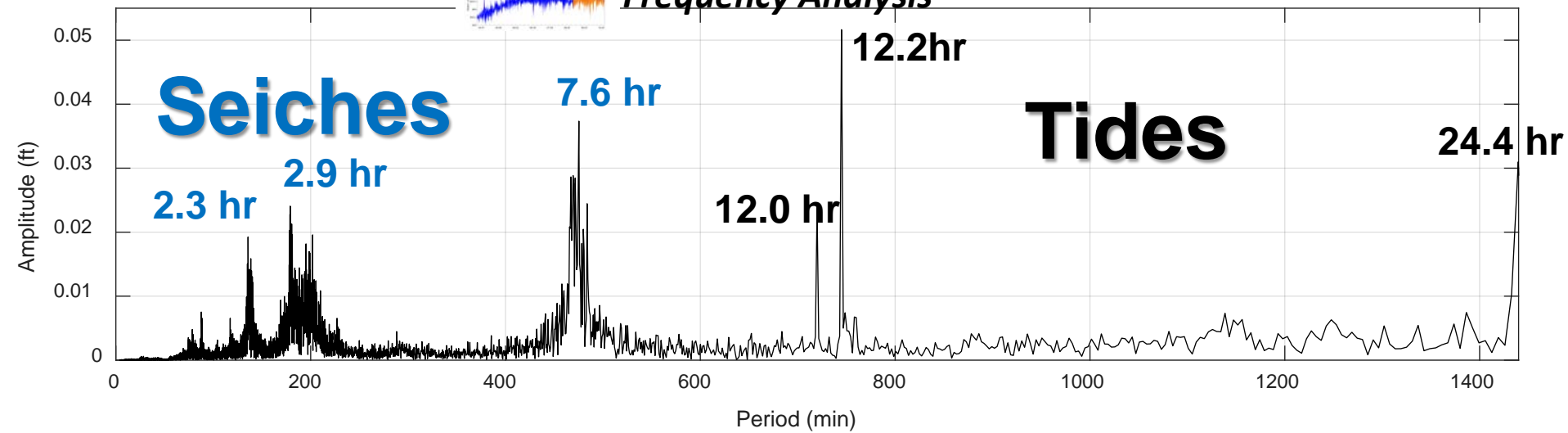
2019



**Moving Storm**



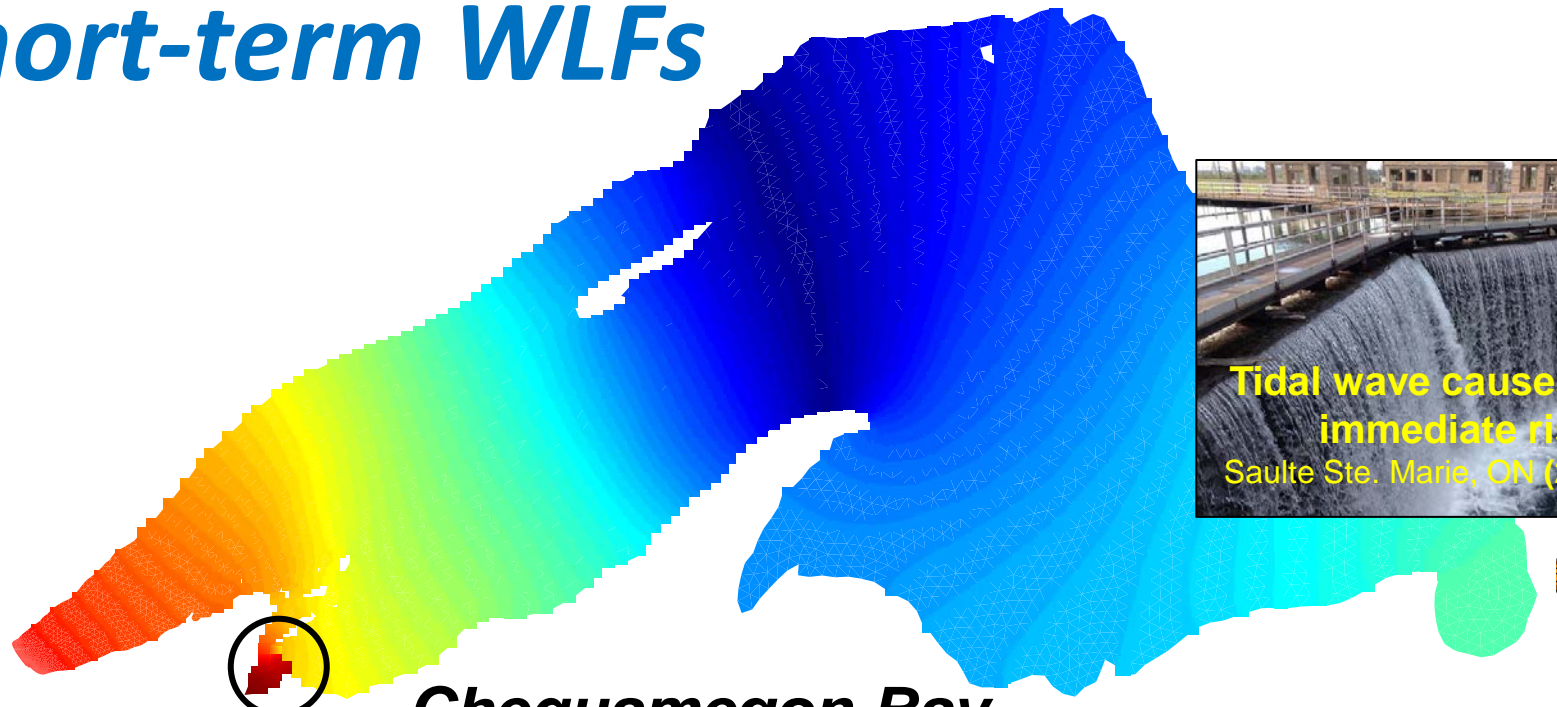
## Frequency Analysis



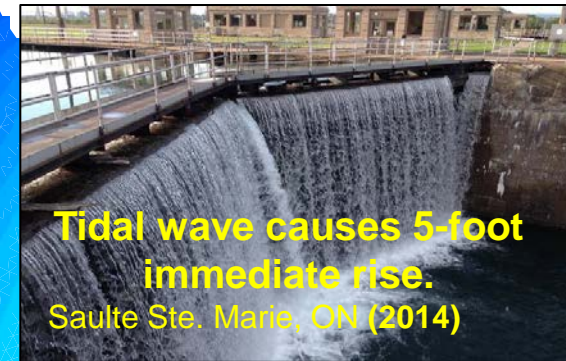
*FEMSEICH Modeling*

PERIOD = 7.5 hours

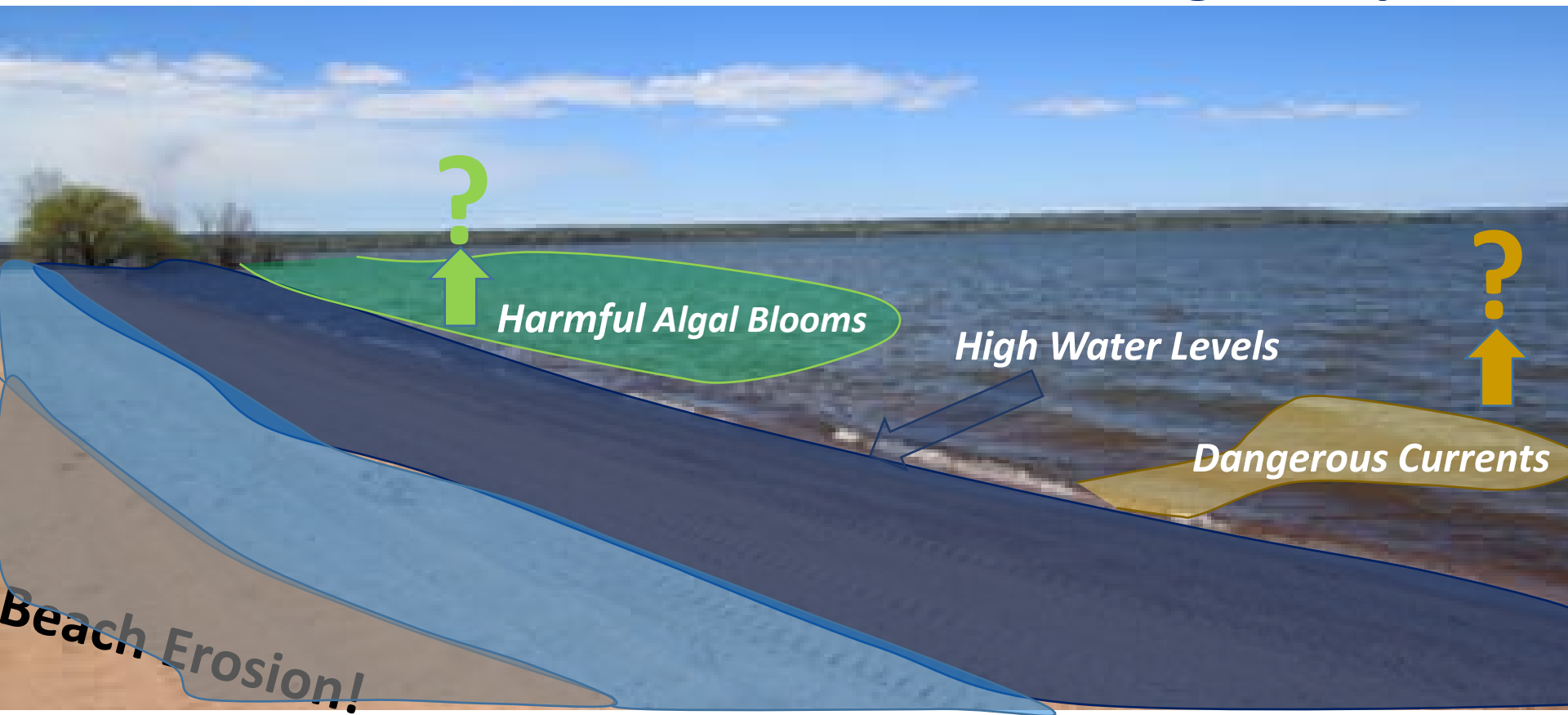
## Short-term WLFs



**Chequamegon Bay**



# To Wisconsin Coastal Beaches Working Group



## Water Level Fluctuations (WLFs)

Climate Driver

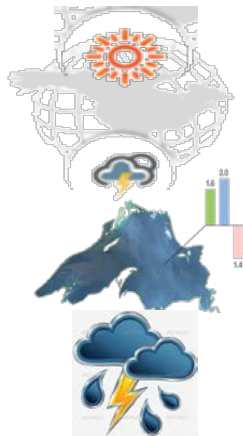
**$3.2 \pm 0.2$  ft**

Hydrological Driver

**$1.2 \pm 0.8$  ft**

Weather Driver

**2.0 ft**







# Dangerous Currents

- Currents that can pull swimmers *away from the shore*.

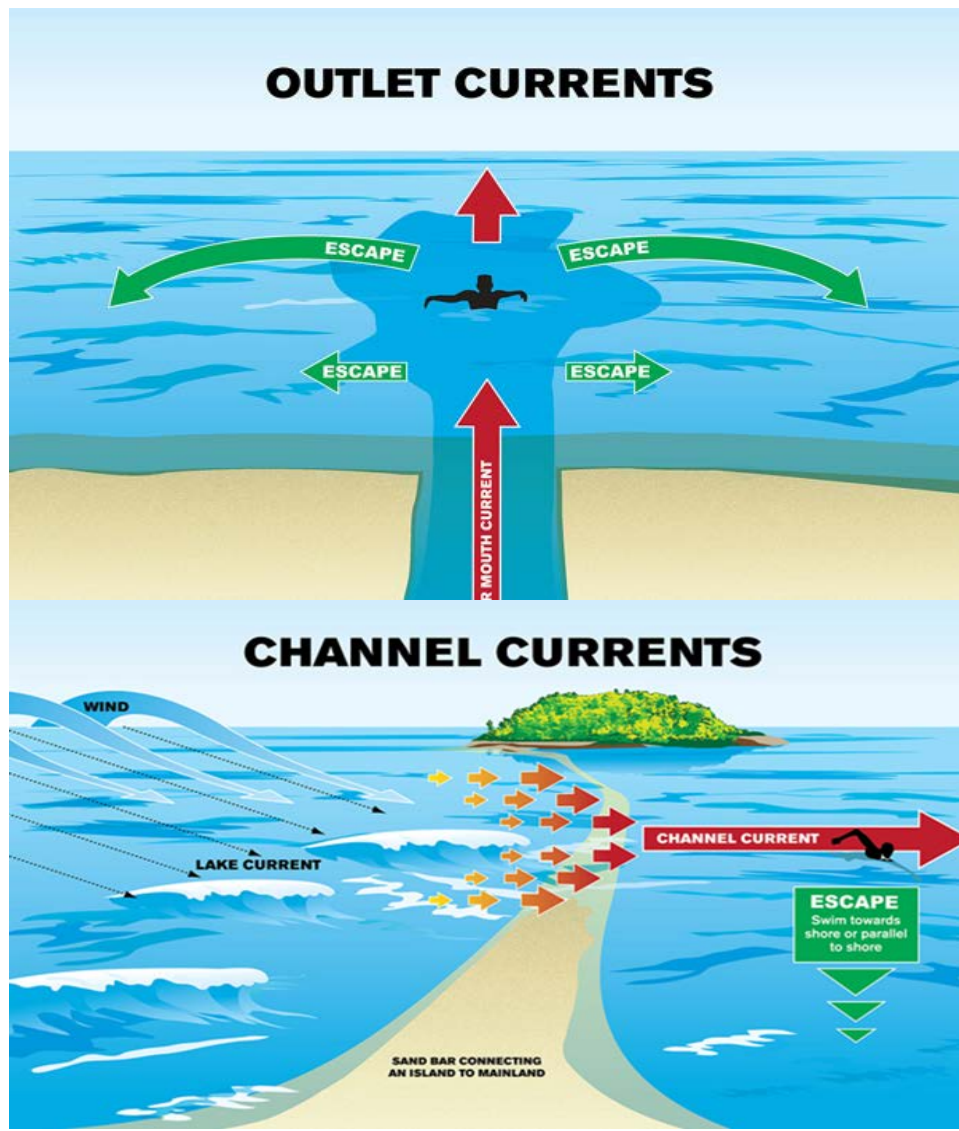
## Rip Currents

Speed: 2mph (3 ft/s)

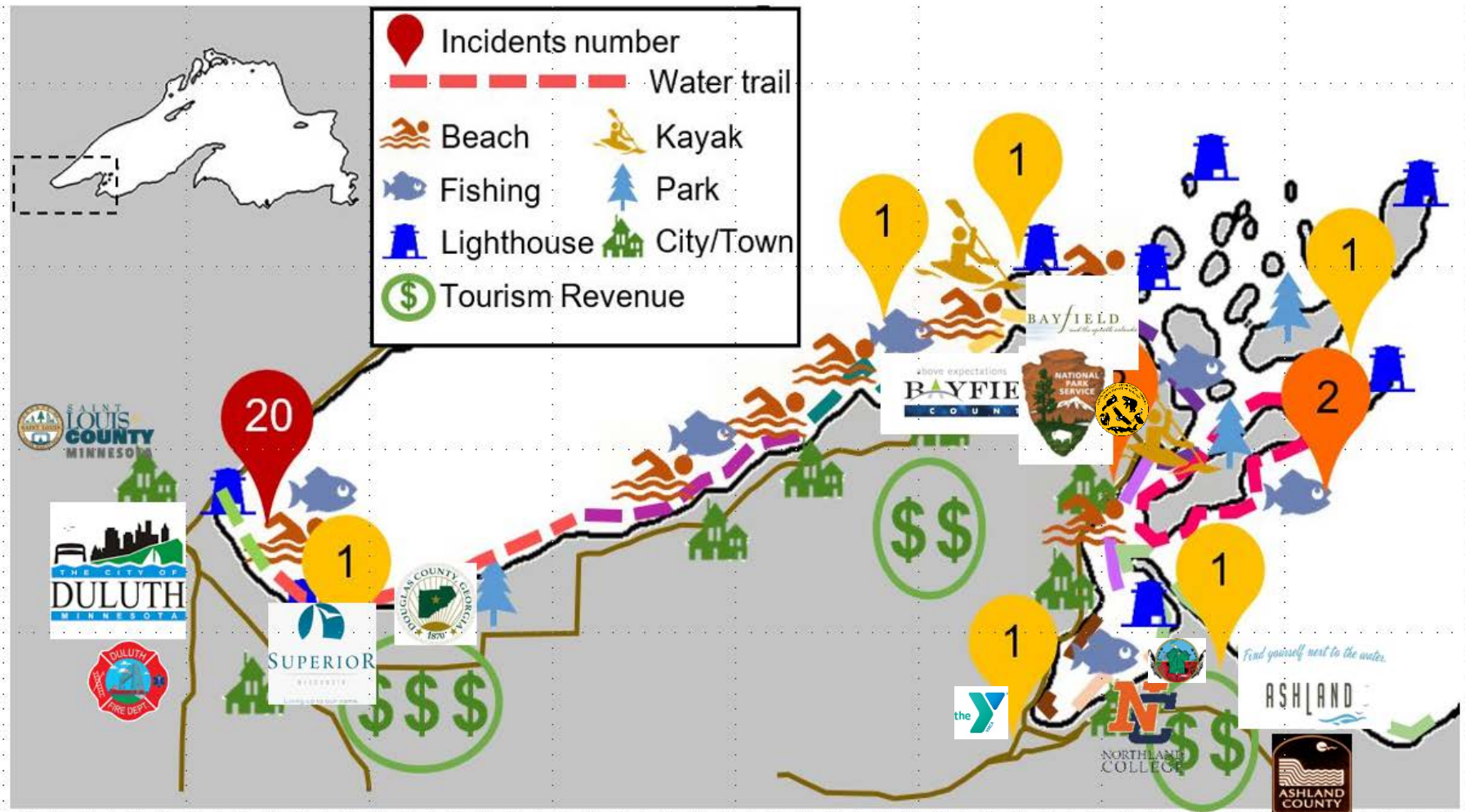
Spacing: 30 ~ 300 ft

Time: 2 ~ 30 min

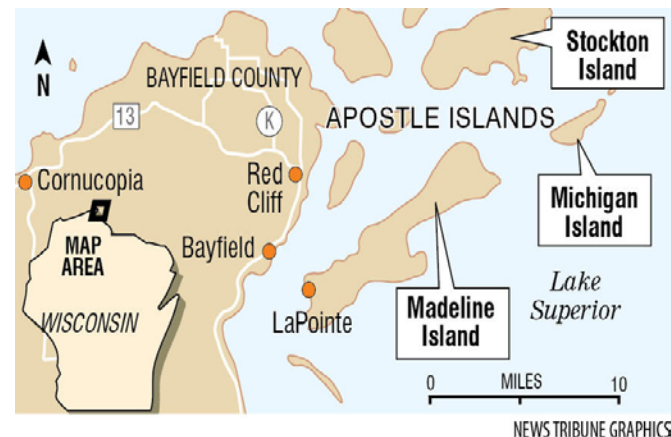
- **Dangerous currents** can be like *outlet* or *channel currents*.
- **Dangerous currents** can occur *near the structures* at lower speeds.



# Characterizing and Forecasting *Dangerous Currents* on the South Shore of Lake Superior in Minnesota and Wisconsin

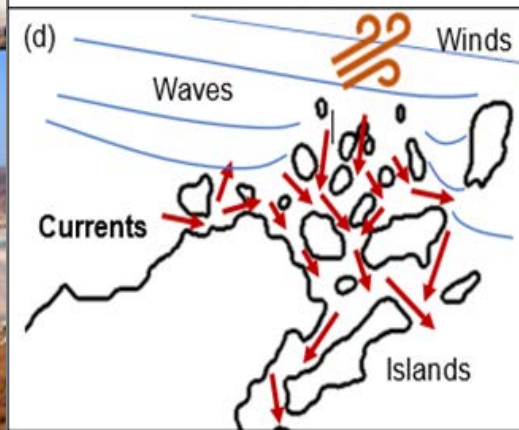
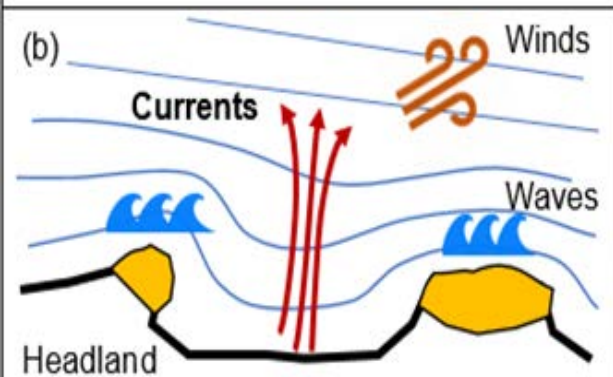
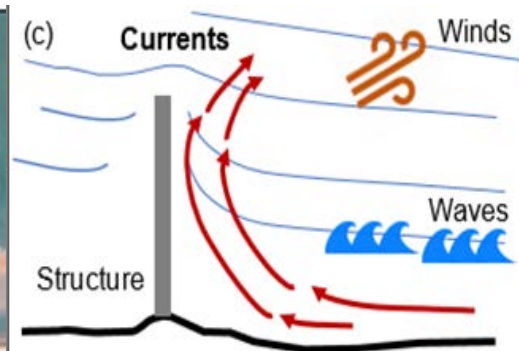
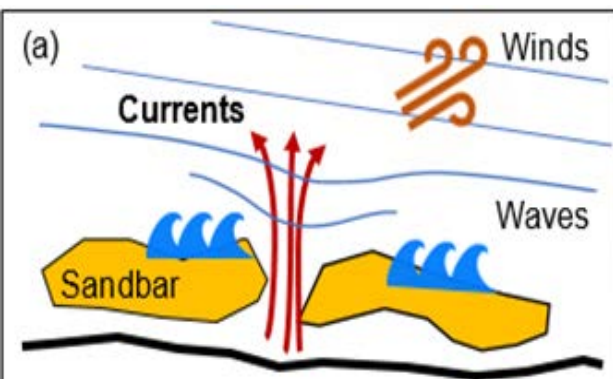






NEWS TRIBUNE GRAPHICS

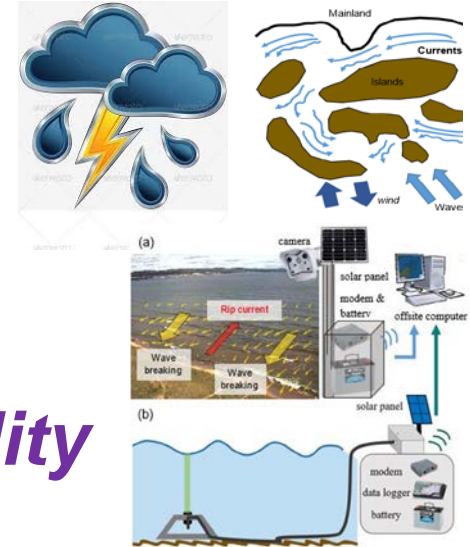
*Little is known* about the occurrences of *dangerous currents* on the South Shore of Lake Superior in Minnesota and Wisconsin



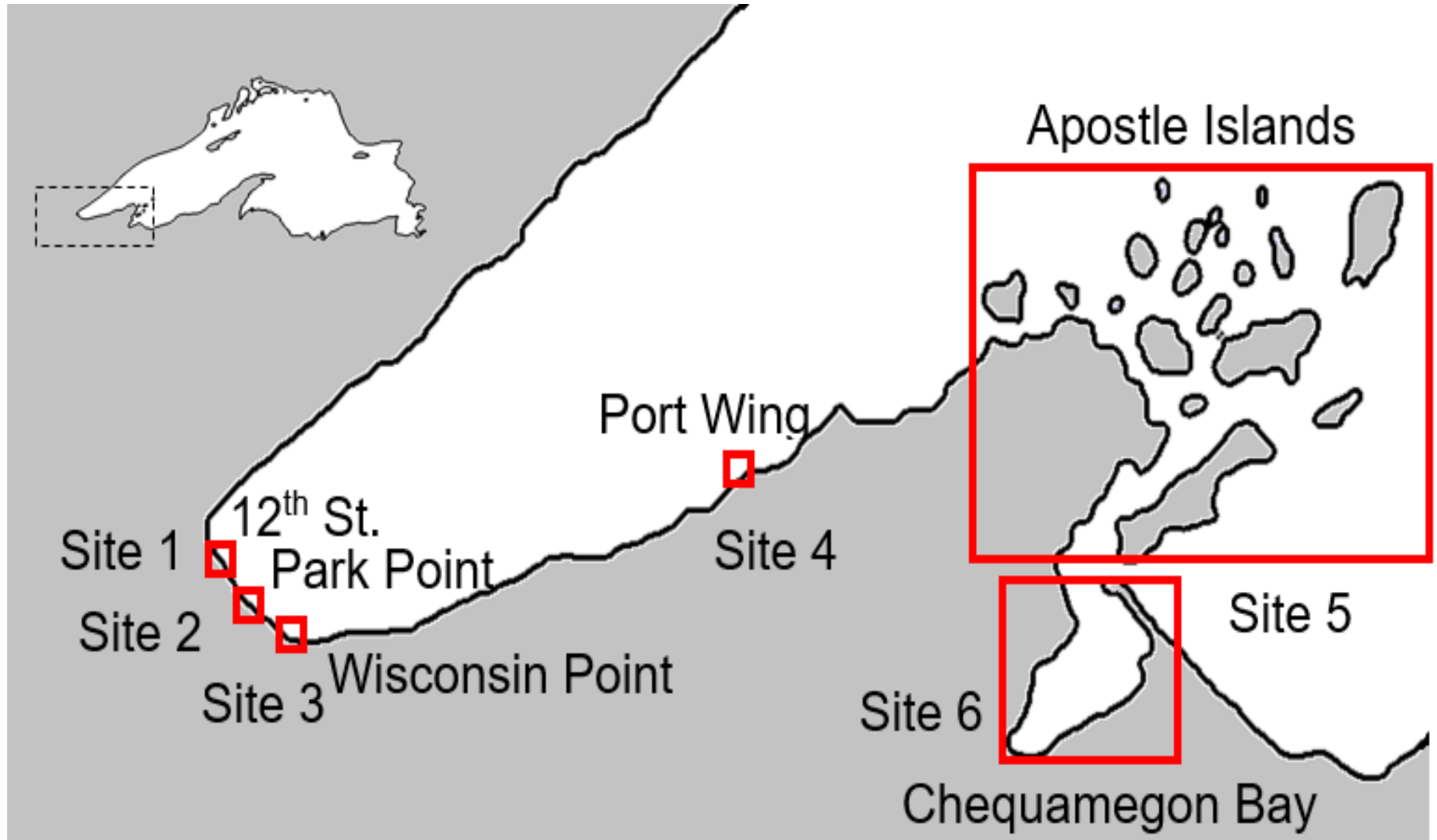


# Project Objectives

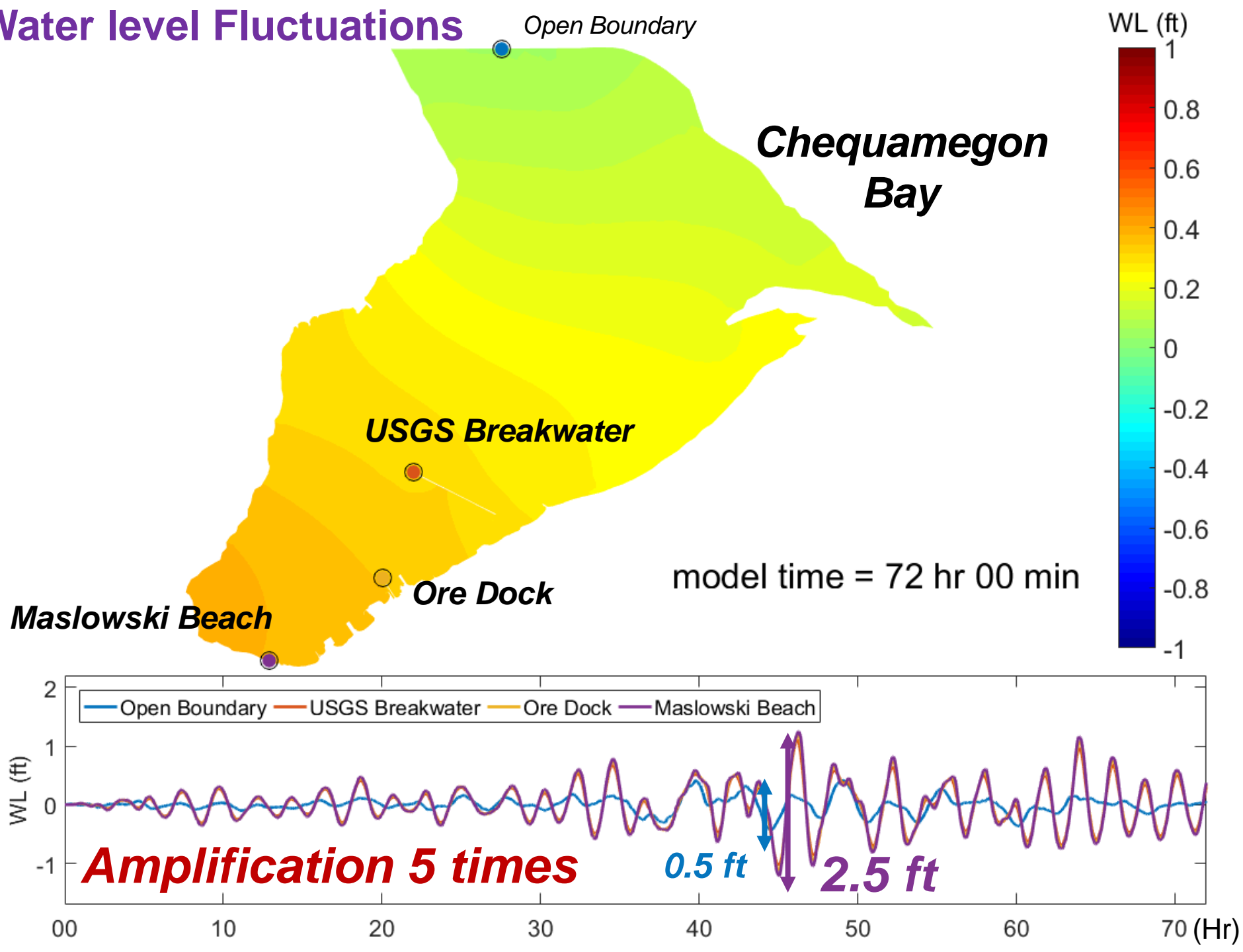
- Characterize **dangerous currents** due to seiches/meteotsunamis due to combined wave processes
- Forecast **dangerous currents** to mitigate **Community Vulnerability**
- Develop an integrated framework of **dangerous currents** for warning, outreach & education, coordination & communication to enhance **resilience** for South Shore of Lake Superior in Minnesota and Wisconsin



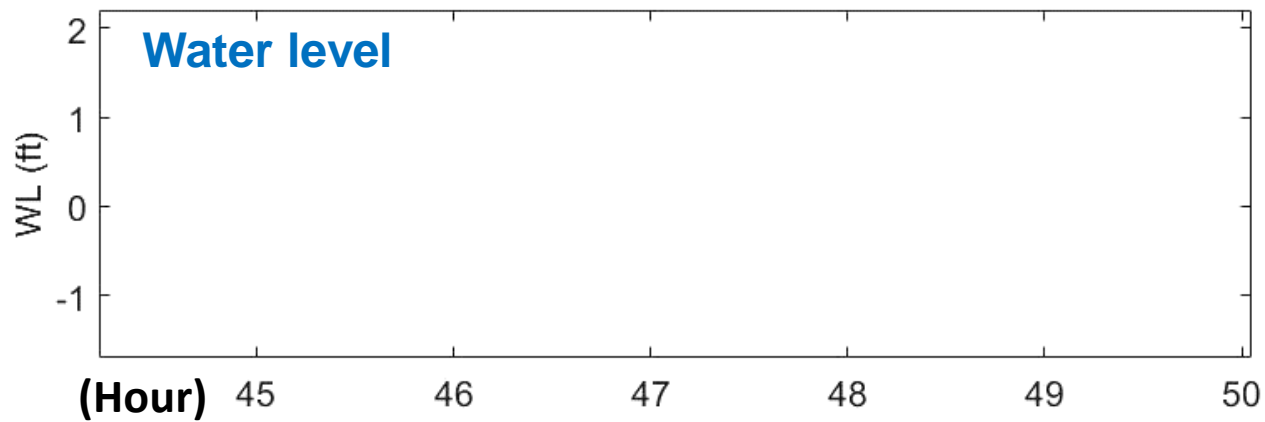
# Project Locations



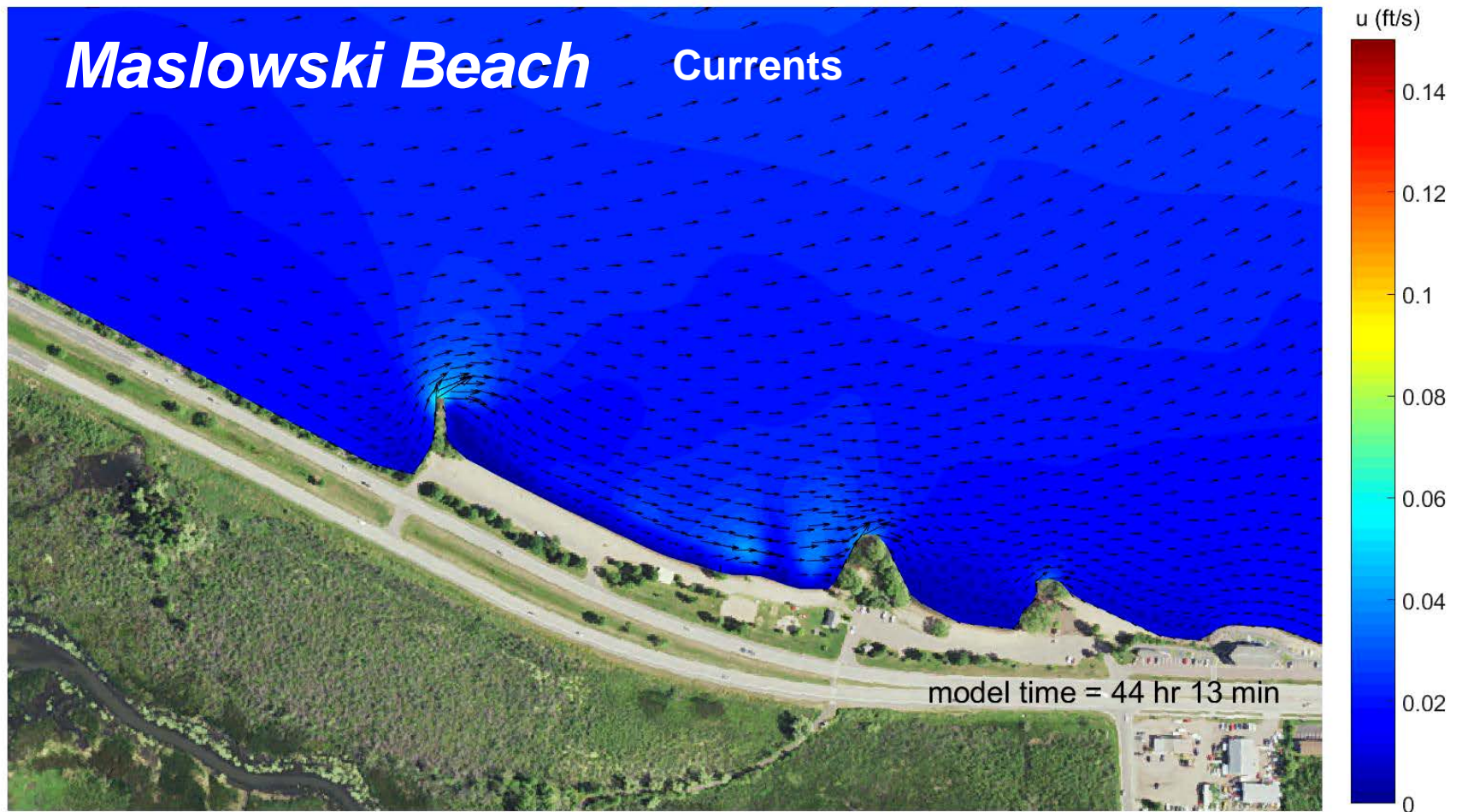
# Water level Fluctuations







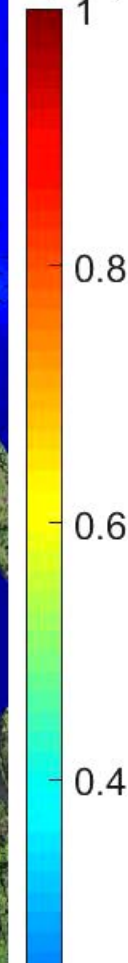
***Dangerous  
Currents?***



# Ore Dock

## Currents

u (ft/s)

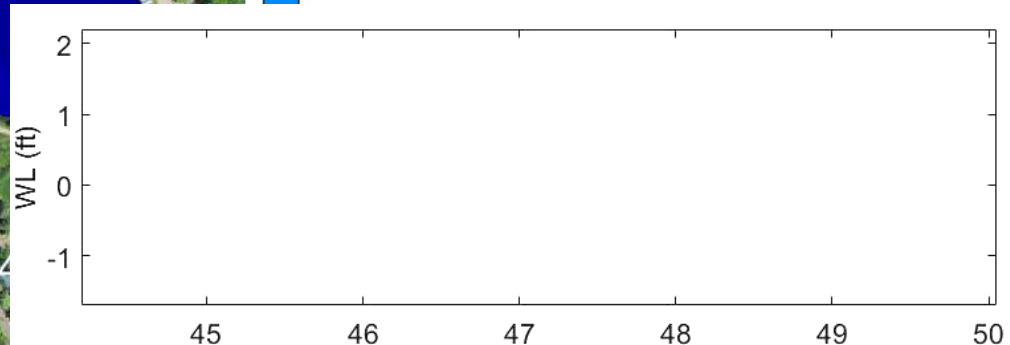


- **Currents**  $> 1$  ft/s near the tip
- **Eddies** swing back and forth

**Dangerous Currents!**

Water level

model time = 44









# Rip Watch Camera Image (2016-2018)

Location: 22<sup>th</sup> St Beach



Calm day pics

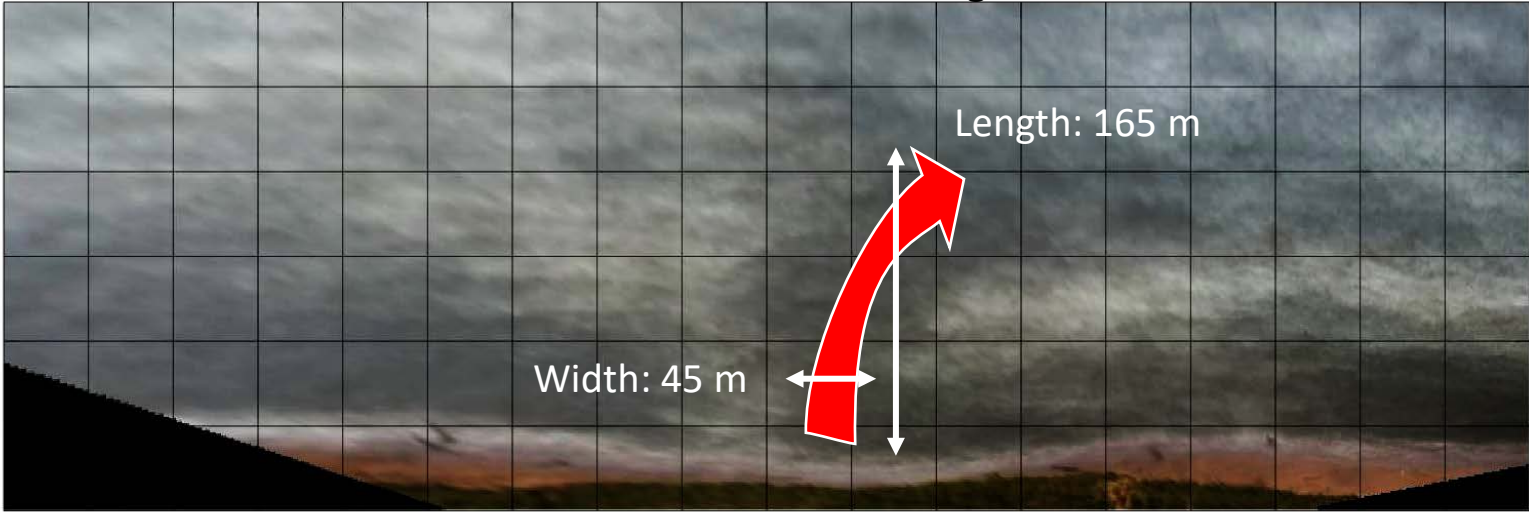


Images of Rip Watch Camera

Location: 22<sup>th</sup> St Beach

Ortho-rectified timex image

50 m  
50 m



# Rip current types

## Type 1) sand bars/rip channels

2016-09-05

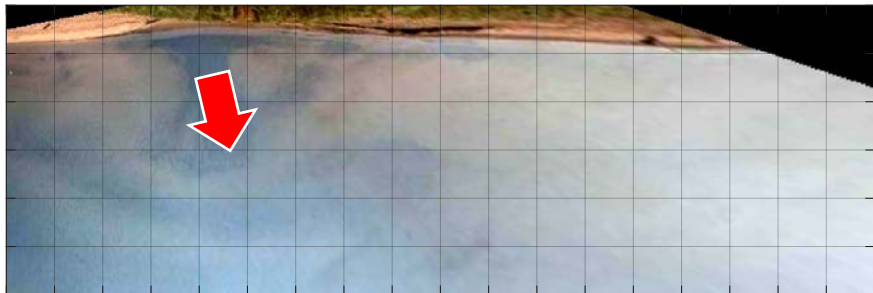


50 m  
50 m

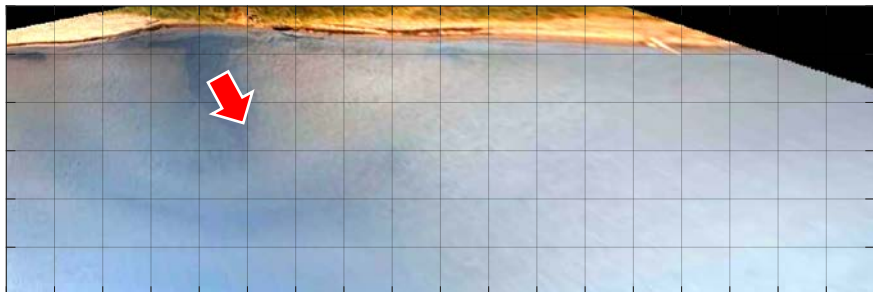
2016-09-17



2016-09-25



2016-09-27



***Active sediments  
– rip currents can  
be on and off***

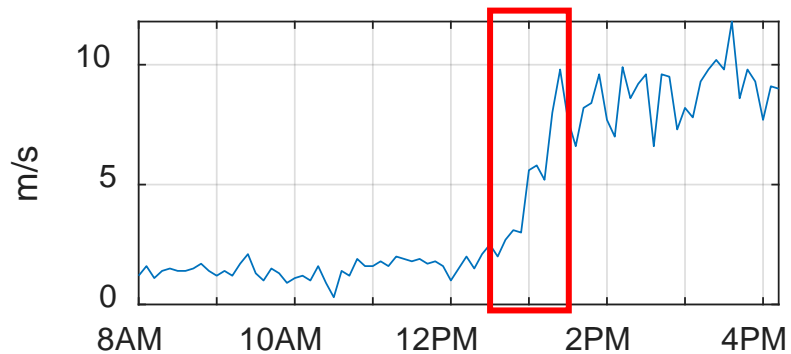


## Type 2)

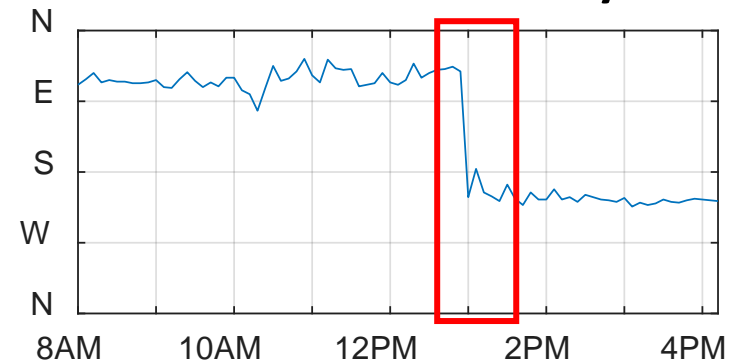
Event: June 19, 2016



**Wind speed rapidly increases**



**Wind direction suddenly shifts**



# Summary of Locations



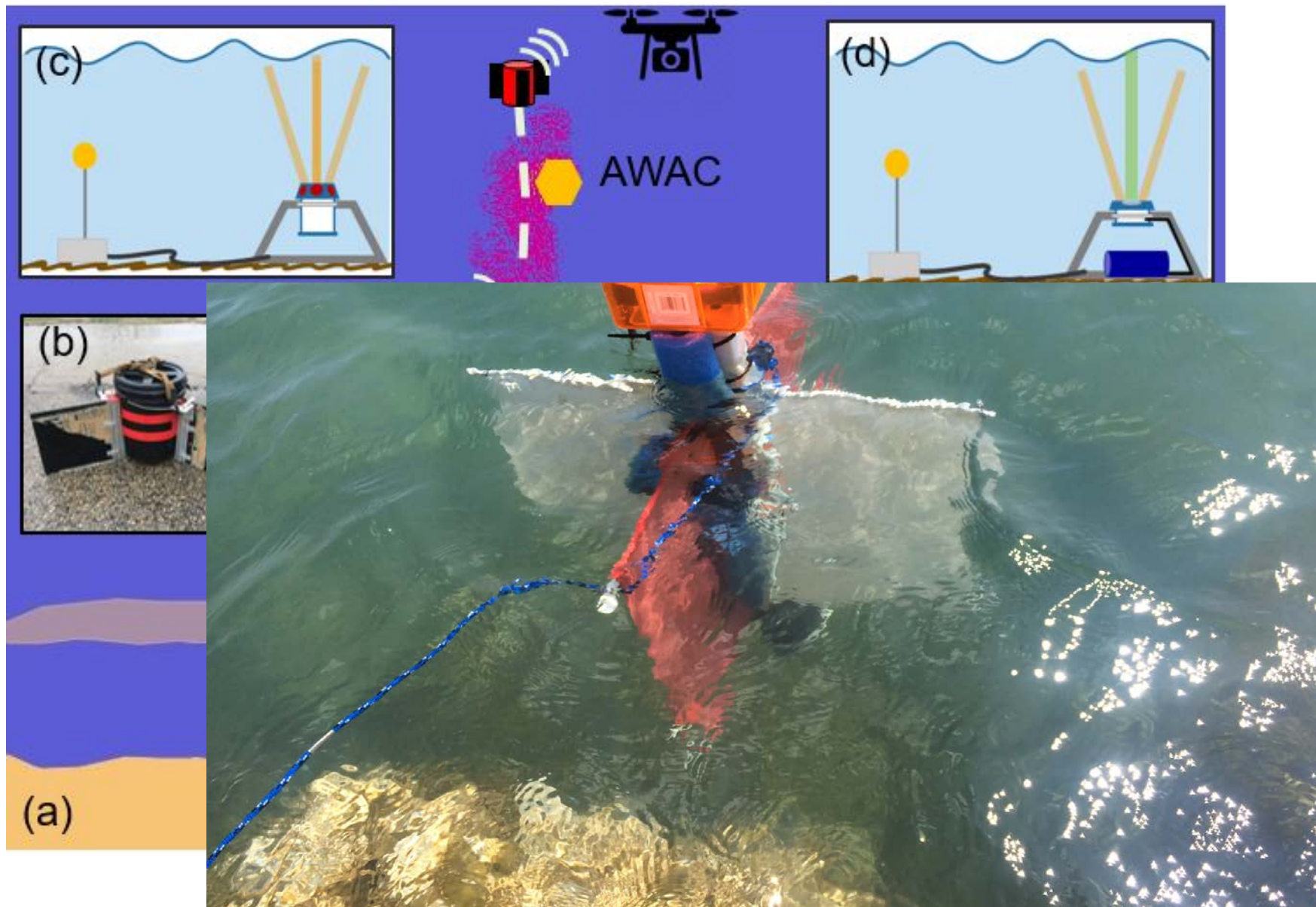
## Ubiquitous topography features

- 1) Near **Beach** – sandbars, rip channels, crescent bars
- 2) Near **structures** – piers, breakwaters

## Identified 7 **Hotspots**

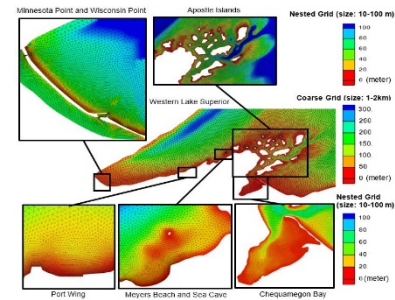
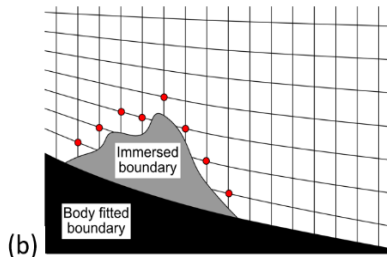
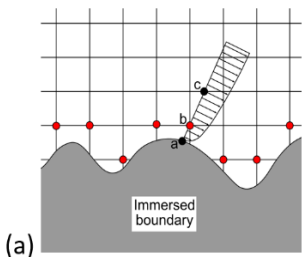
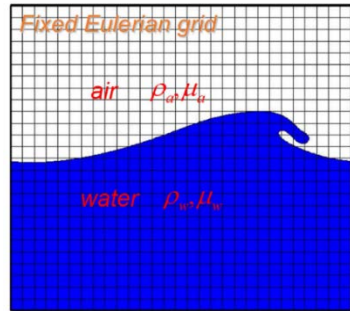
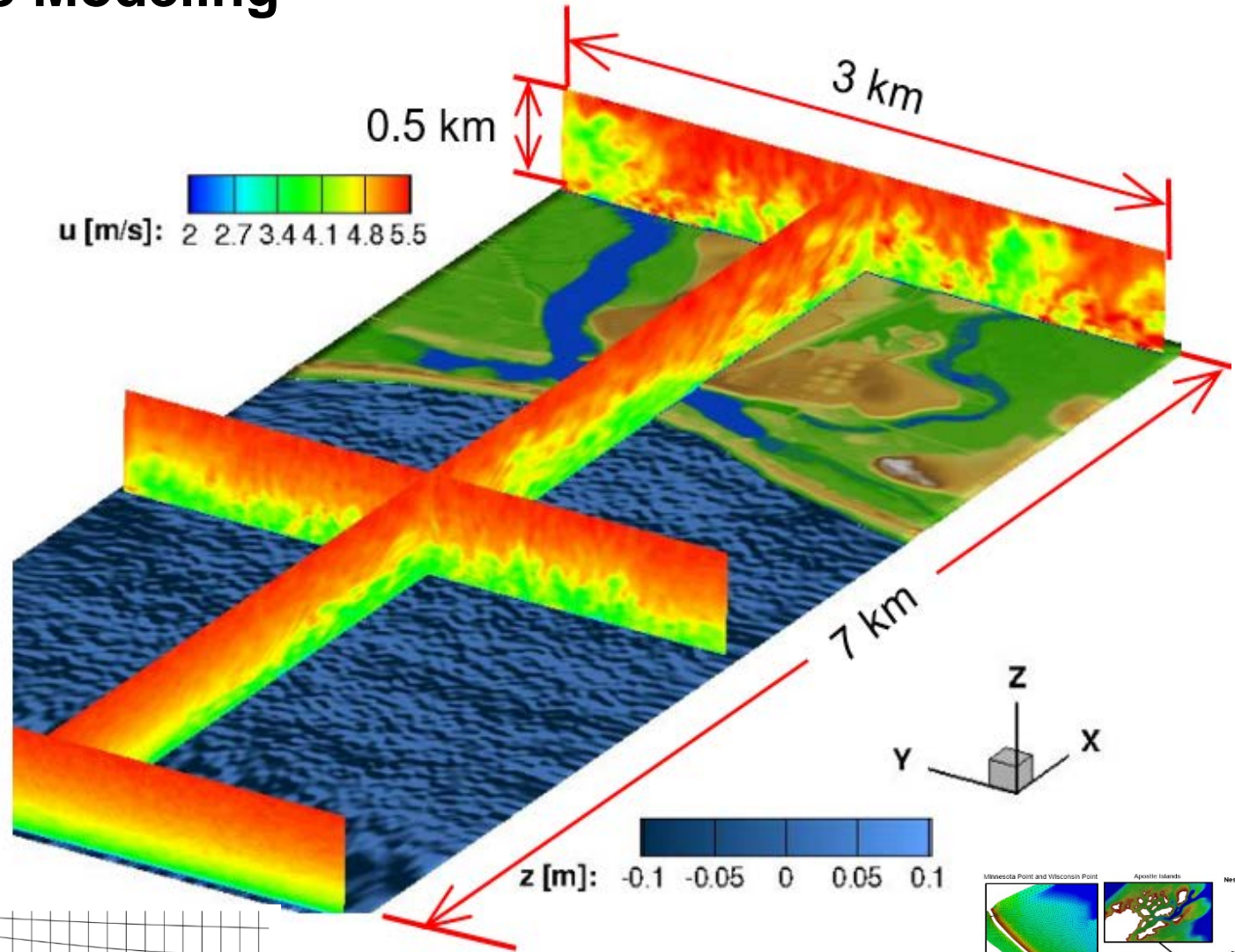
- 1) Long persistence of rip channel
- 2) Small rips spacing
- 3) Large offshore extent of rip channels/bars
- 4) Popular location of public access

# Field Observations



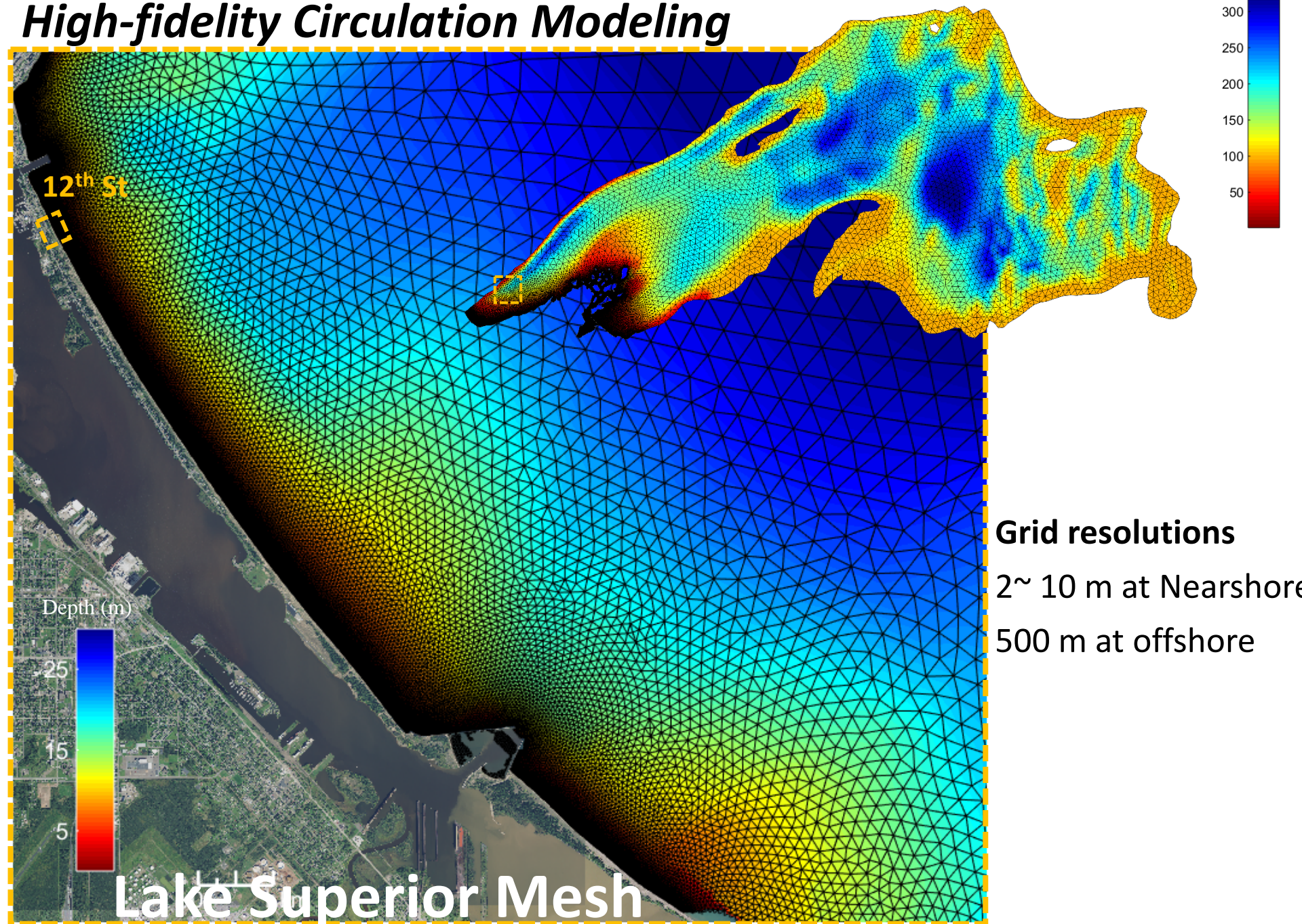


# Cross-Scale Modeling





# High-fidelity Circulation Modeling

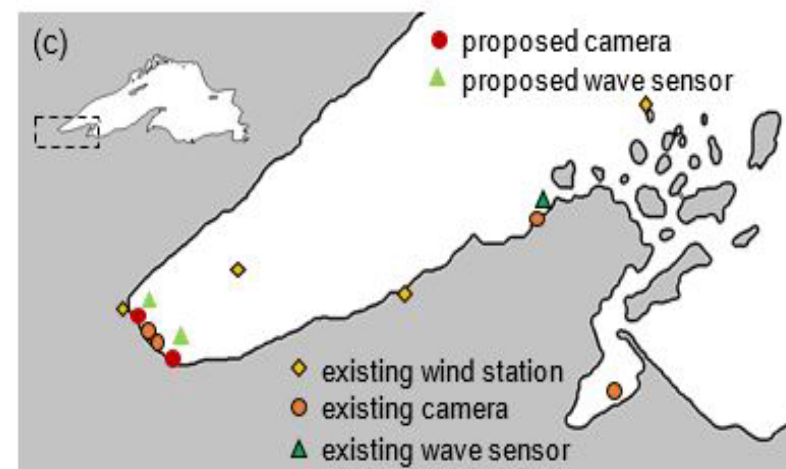
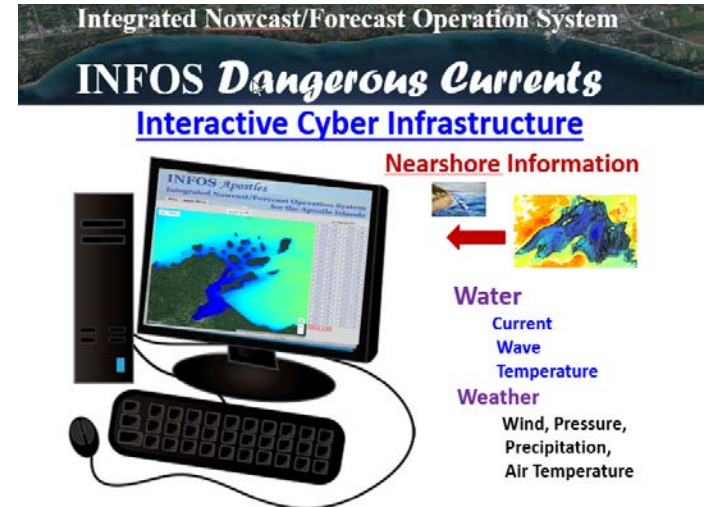
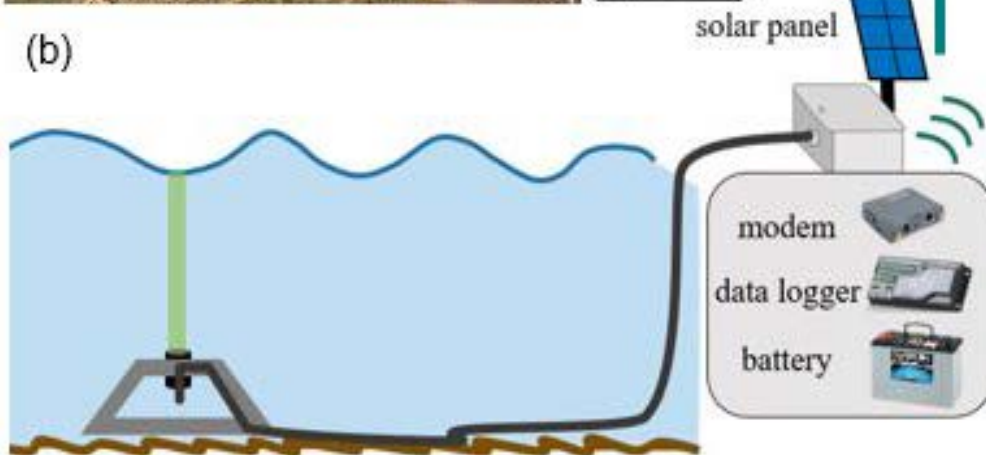
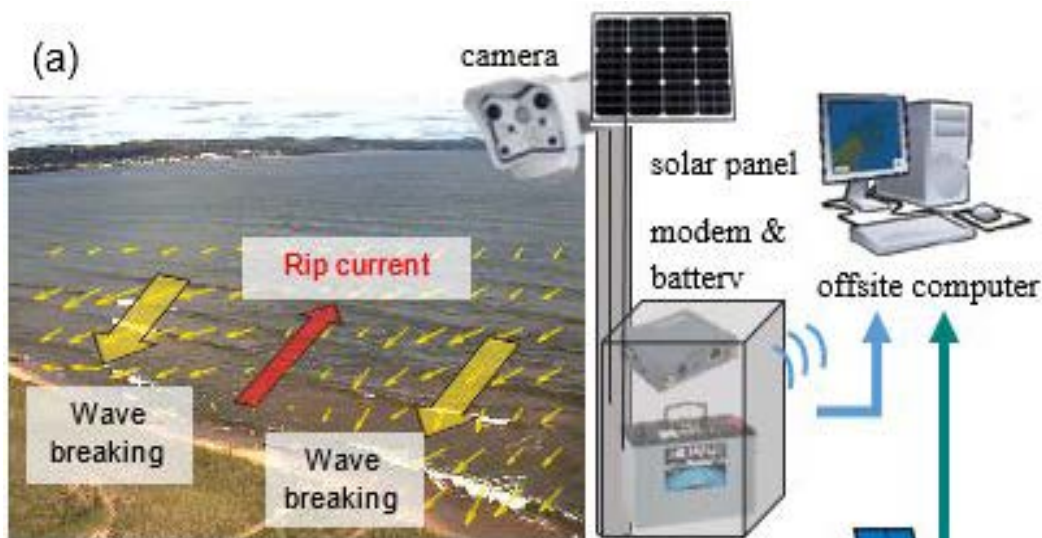




# Approach

## (2) *Dangerous currents* Now-Forecasting

### Real-Time Observations



Forecasting

# Integrated Nowcast - Forecast Operational System (INFOS)

Real-time Observations

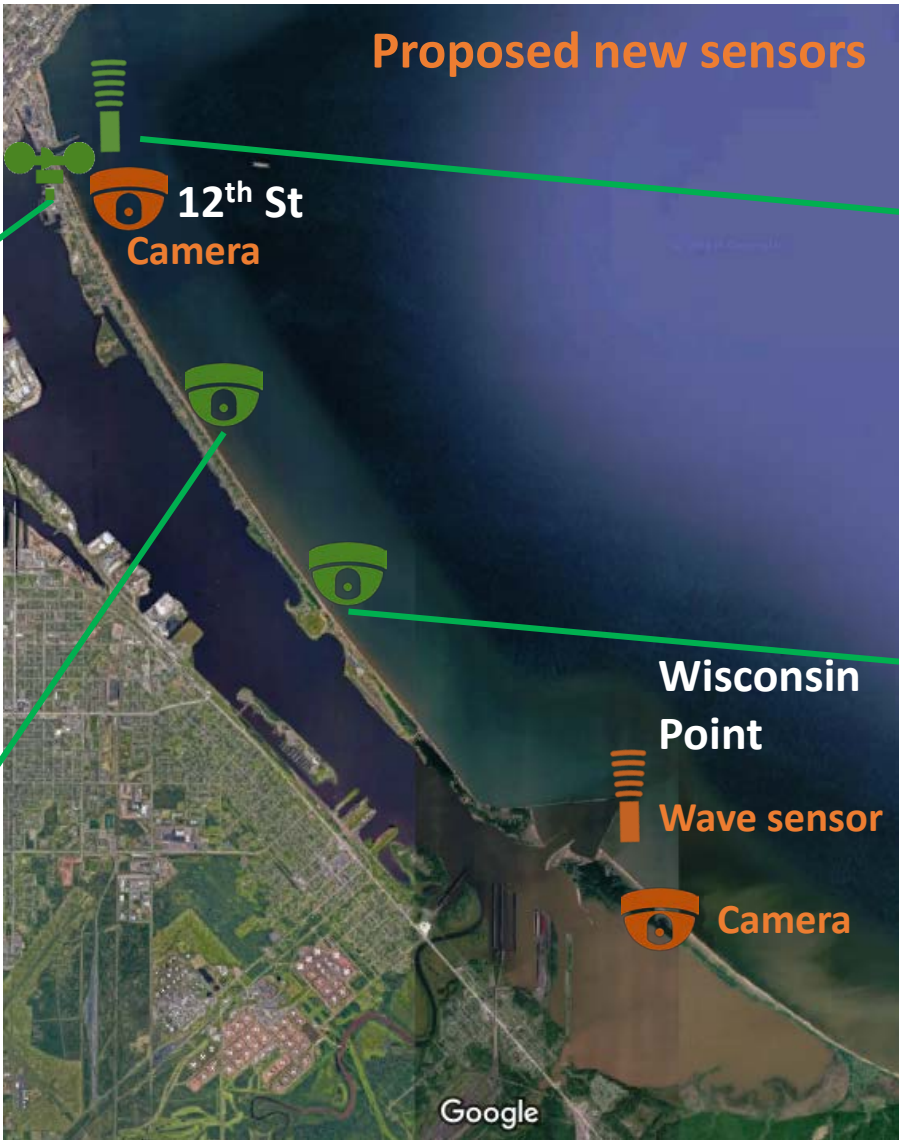
Existing sensors



NOS weather station



Camera (22<sup>nd</sup> St)



Proposed new sensors

12<sup>th</sup> St  
Camera



Wisconsin  
Point



Wave sensor



Camera



Echologger

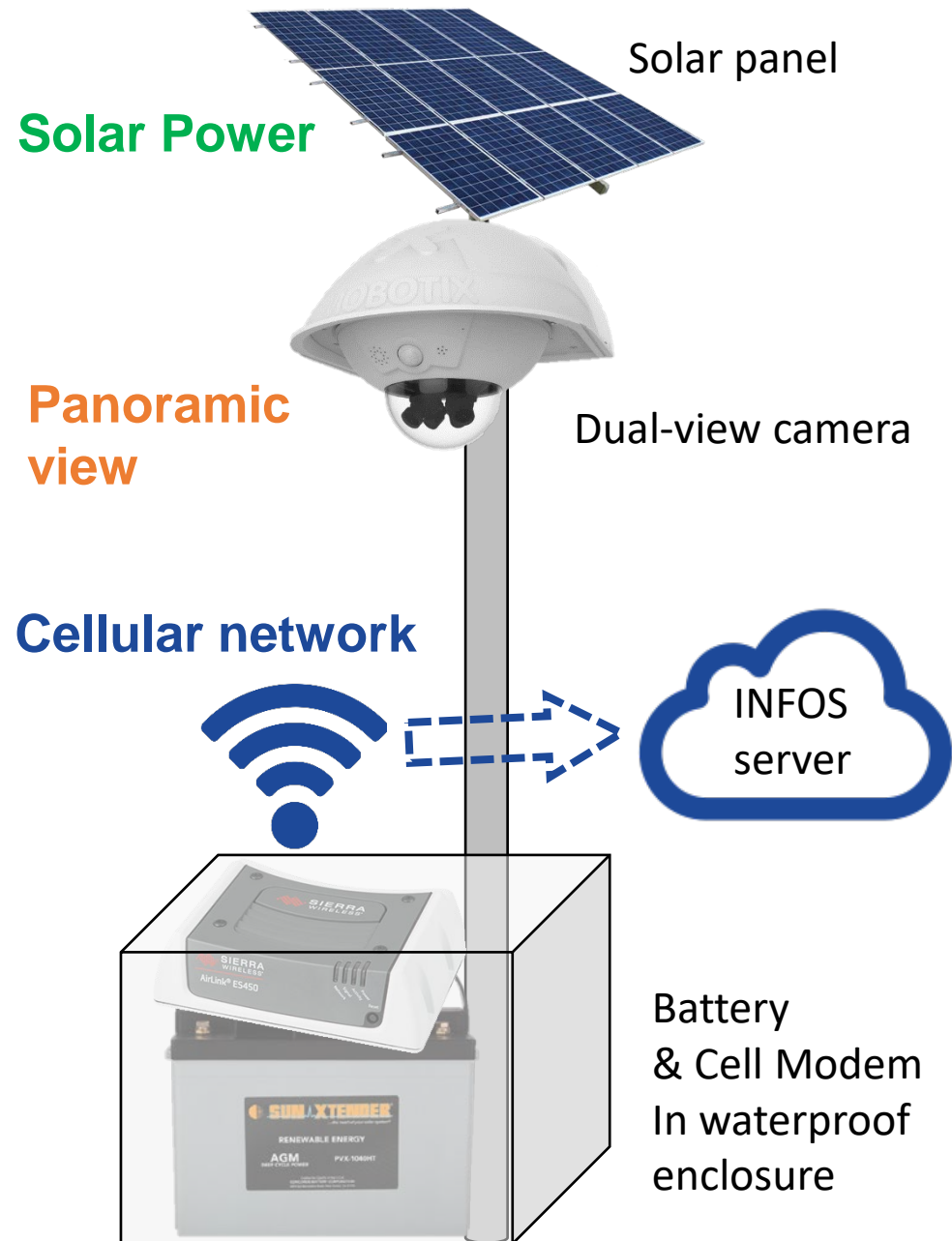
Wave sensor



Camera (Park Point)

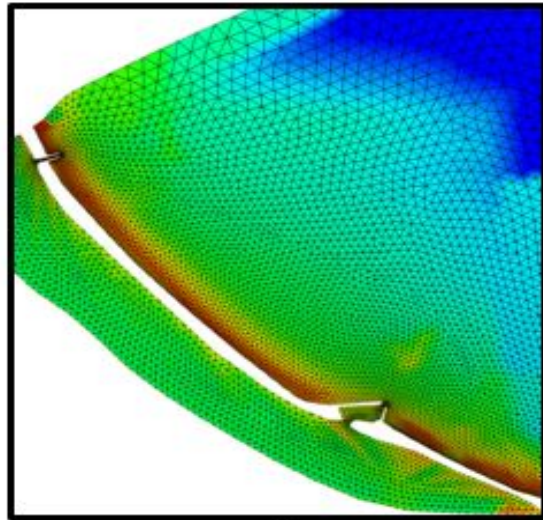


# Proposed camera at 12<sup>th</sup> St

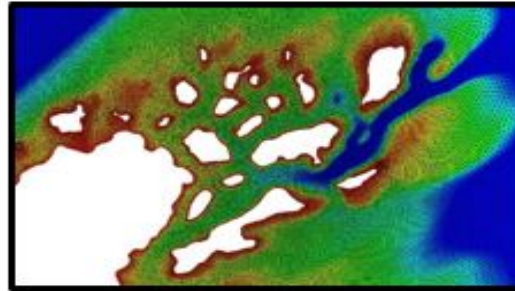


# High-fidelity Circulation Modeling

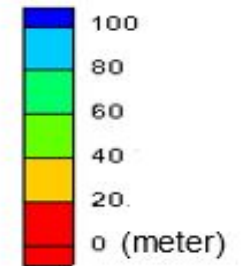
Minnesota Point and Wisconsin Point



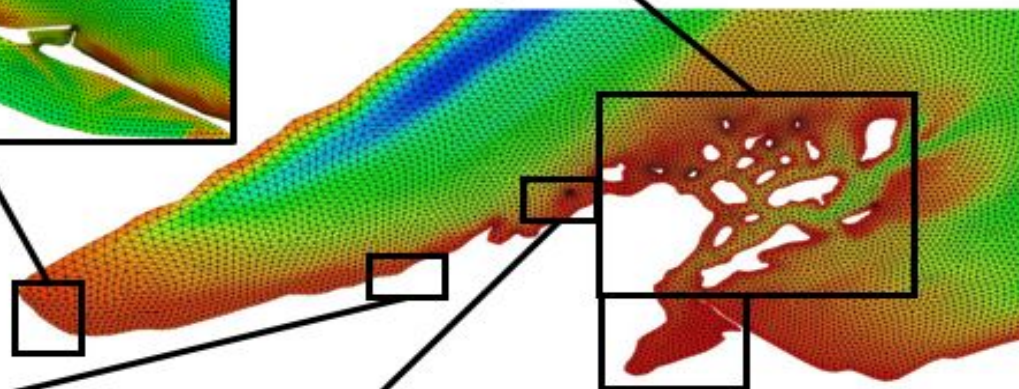
Apostle Islands



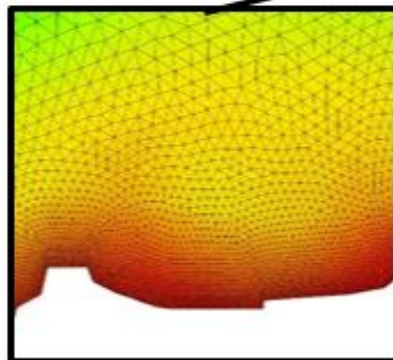
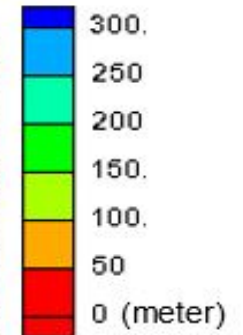
**Nested Grid (size: 10-100 m)**



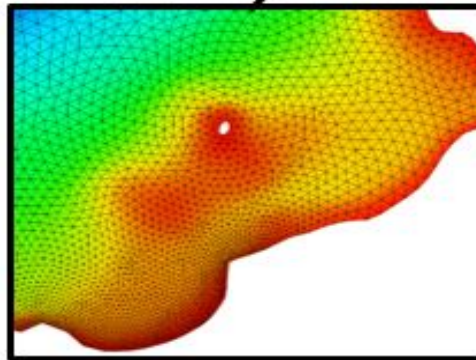
Western Lake Superior



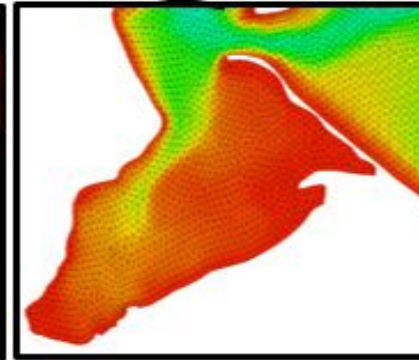
**Coarse Grid (size: 1-2km)**



Port Wing

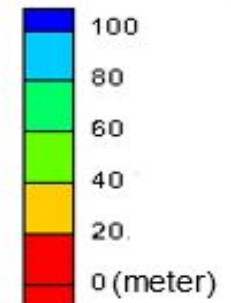


Meyers Beach and Sea Cave



Chequamegon Bay

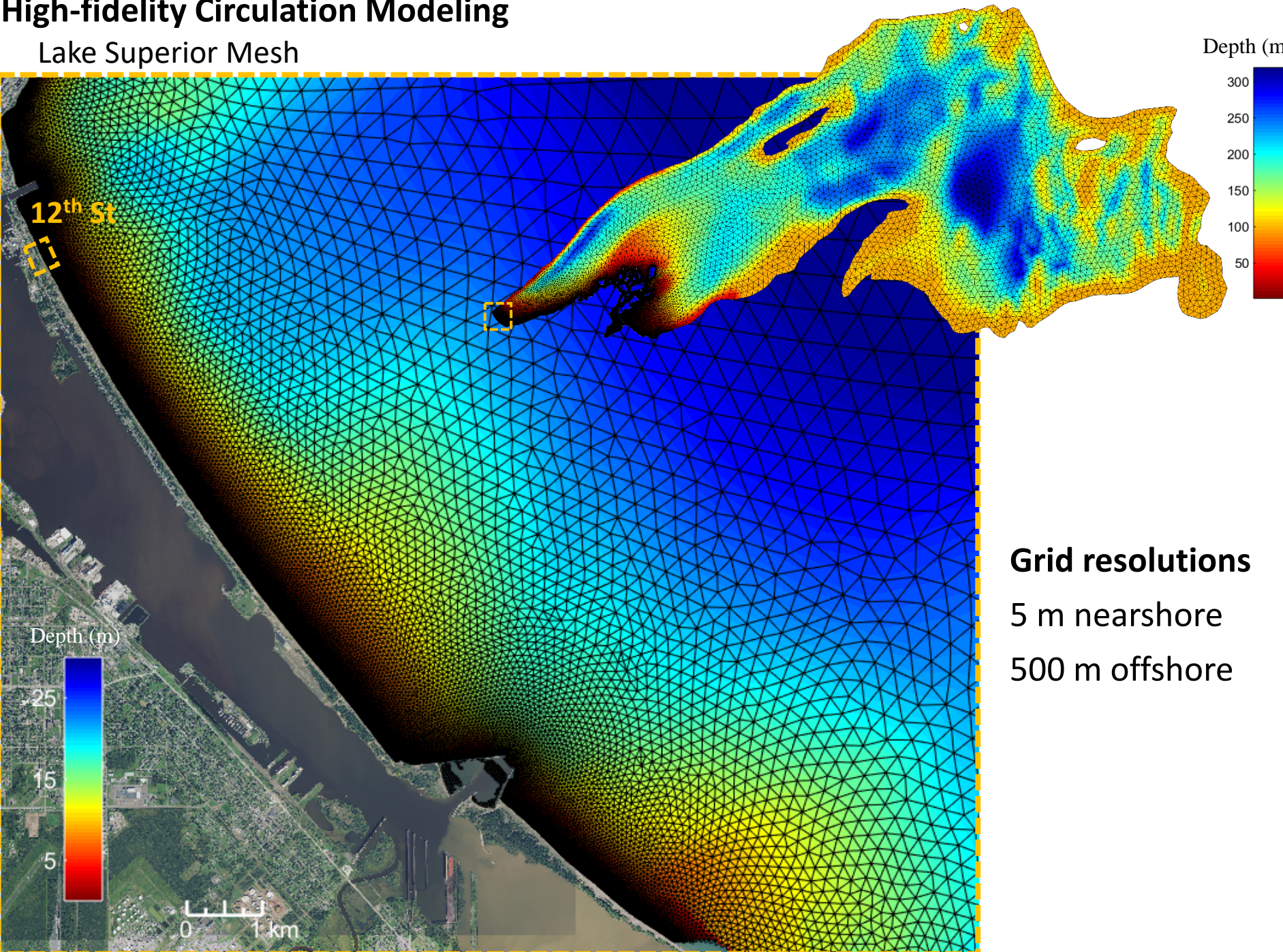
**Nested Grid (size: 10-100 m)**





# High-fidelity Circulation Modeling

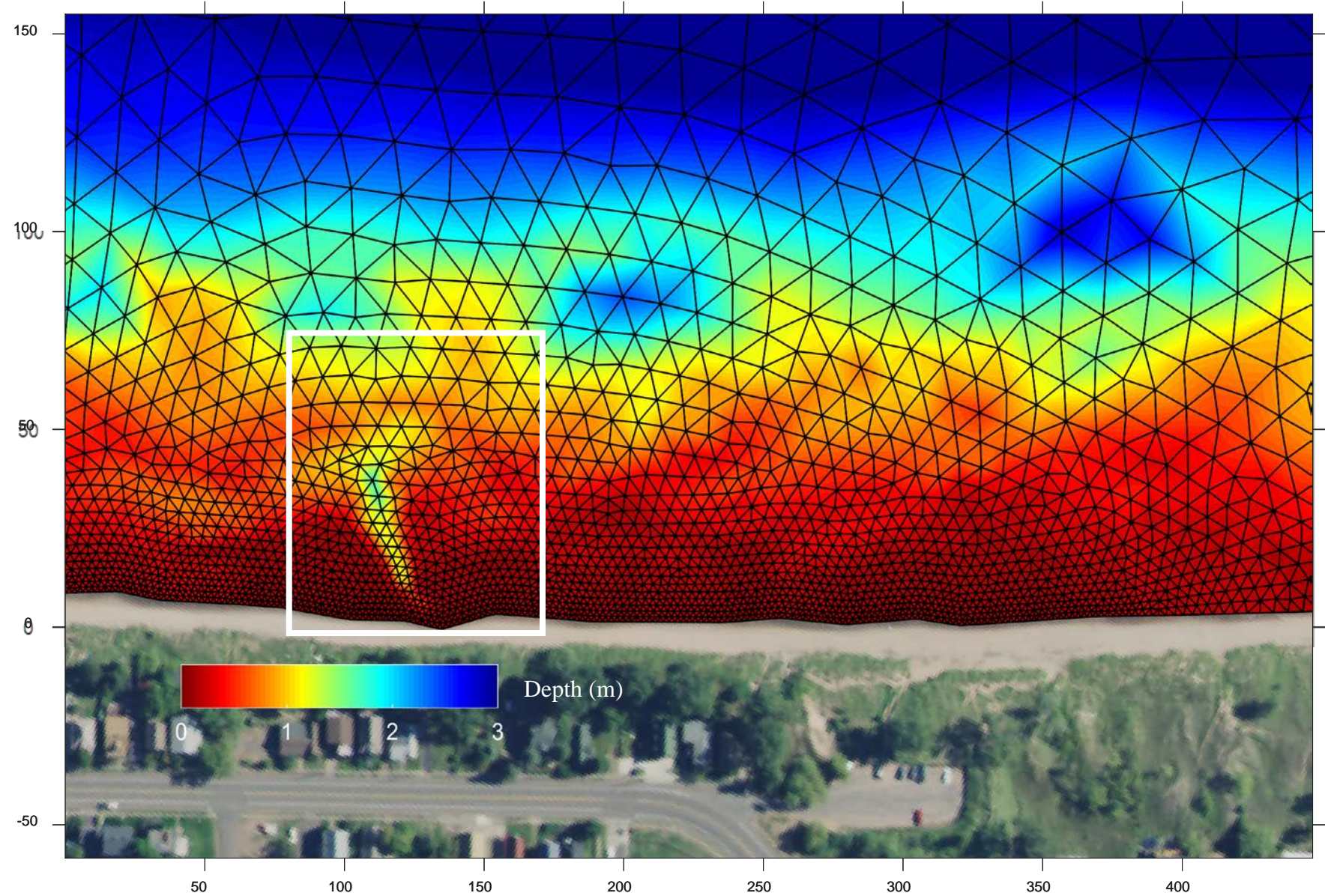
## Lake Superior Mesh



**Grid resolutions**  
5 m nearshore  
500 m offshore



Example: 12<sup>th</sup> St Beach **High-resolution Unstructured Mesh for Rips (HUMoR)**

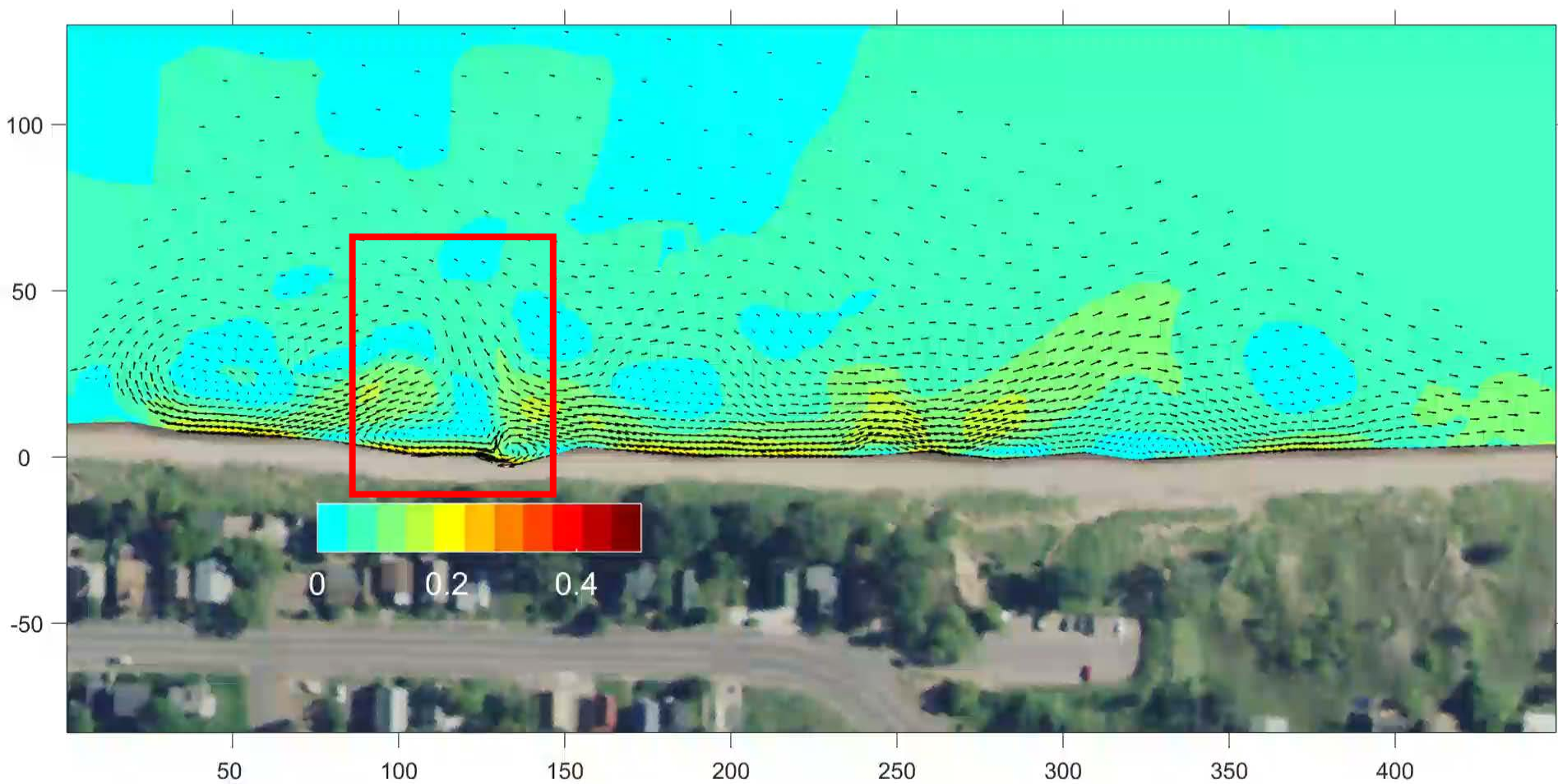


**Grid resolutions - 2 m at shoreline**



# Aug 10, 2016

12 PM-17 PM



*Causes* of *dangerous currents* have yet been fully understood

• Dark Point Beach (2002, 2017, 2018)

