Investigation of Surface Wind Input for Coastal Zone Applications

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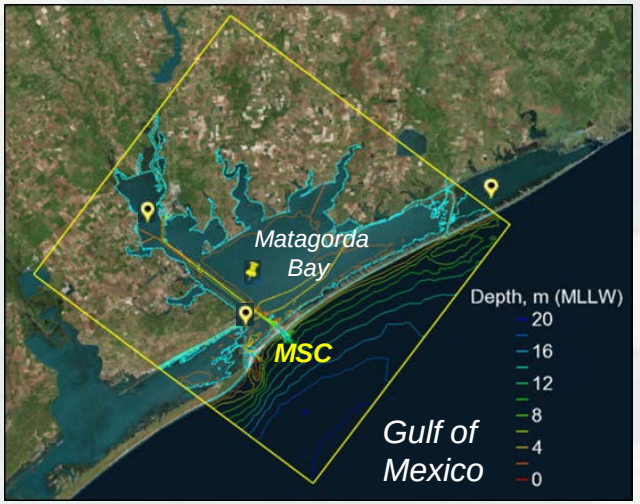
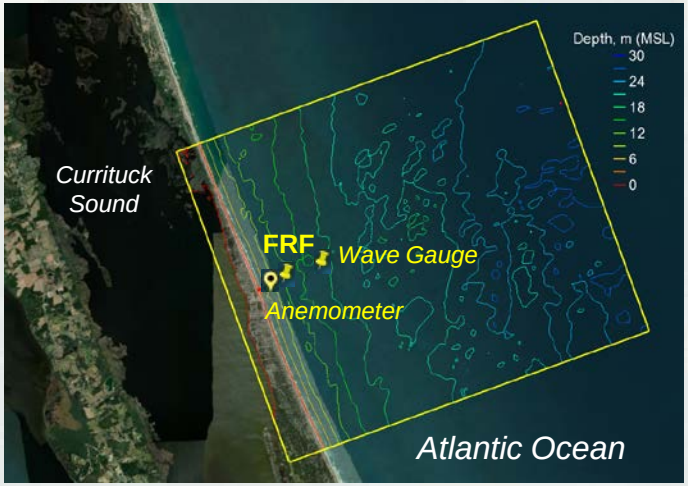
CIRP Technical Discussion

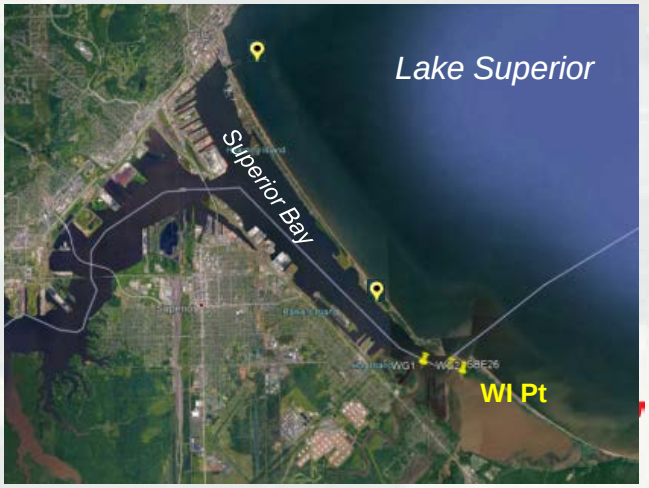
5 February 2019

Improve Wind Input for Coastal Applications

- **Objective:** improve wind input for engineering applications in coastal zone, bays and estuaries
- **Advancement:** provide USACE user community more reliable and accurate wind input for various applications
- **Products:** document research findings and provide a user guide on procedure for improved wind input



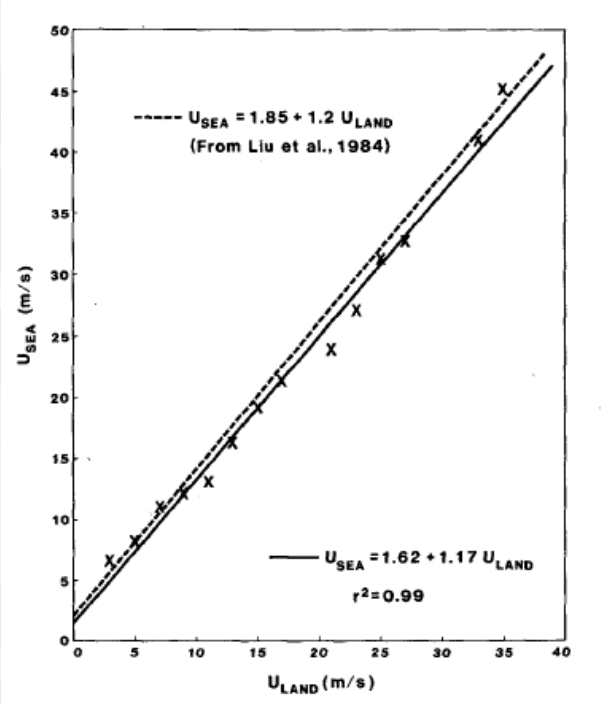




Correction of Land-Based Wind Data for Offshore Applications

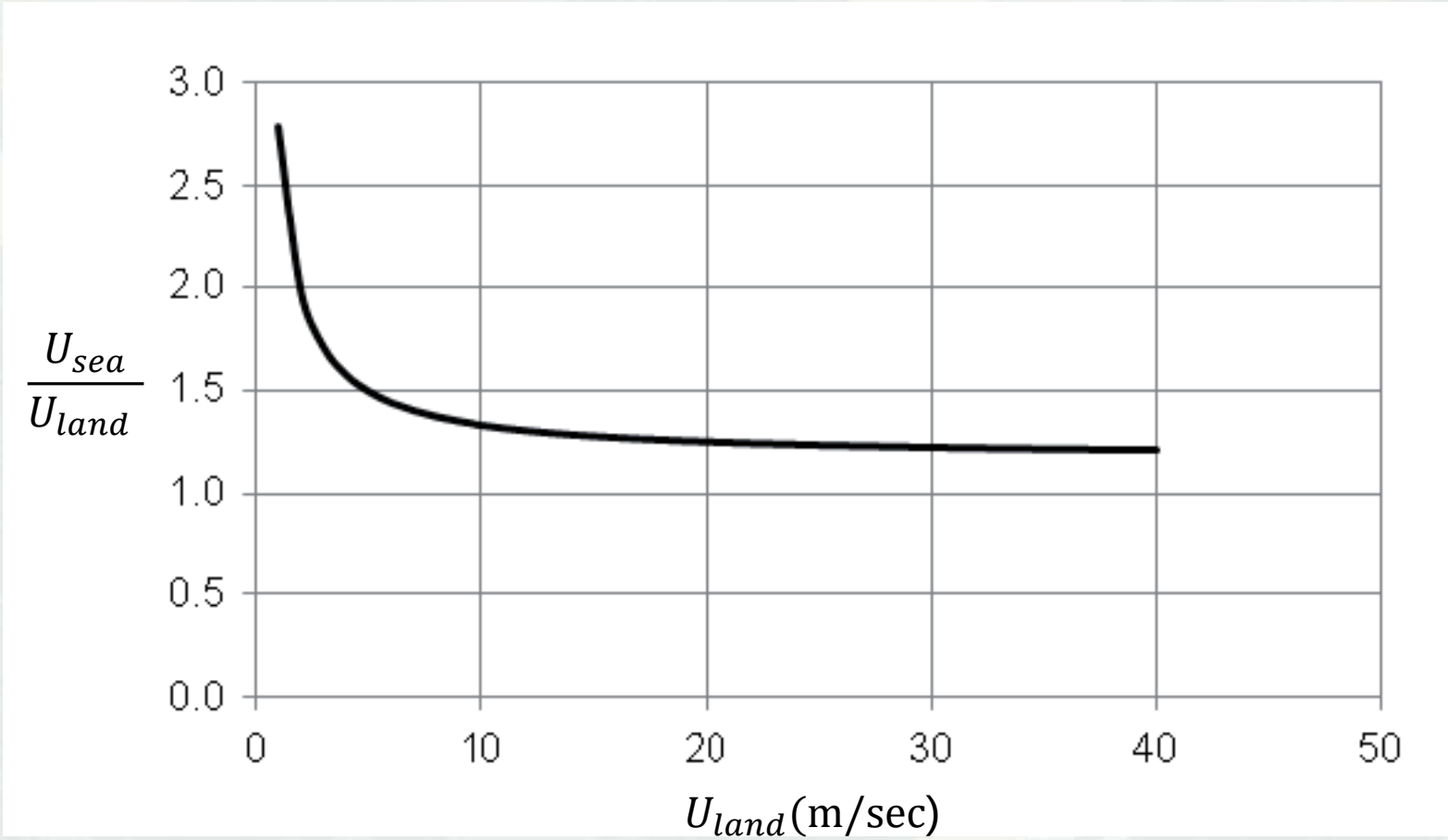
(1) $U_{sea}(\mathrm{m/sec}) = 1.85 + 1.2\ U_{land}(\mathrm{m/sec})$ (Liu et al., 1984)

(2) $U_{sea}(\mathrm{m/sec}) = 1.62 + 1.17\ U_{land}(\mathrm{m/sec})$ (Hsu, 1985)



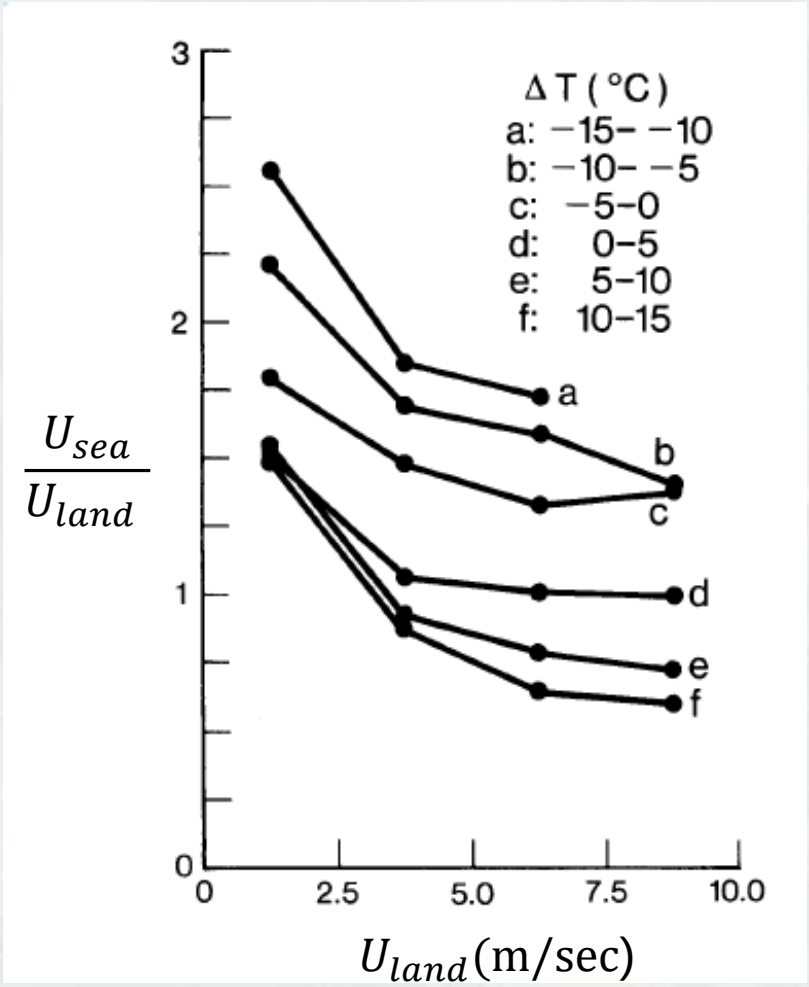
- Eq.(1) is based on graphs by Resio and Vincent (1977) for the Great Lakes region
- Eq.(2) is based on NDBC, NOAA, Oil Rig, Airport data
- Wind is blowing from land to sea
- U_{sea} at 20-m level, above MSL

Plot of $\frac{U_{sea}}{U_{land}}$ versus U_{land}



- Based on Eq.(2) by Hsu, 1985

Plot of $\frac{U_{sea}}{U_{land}}$ versus U_{land} and ΔT

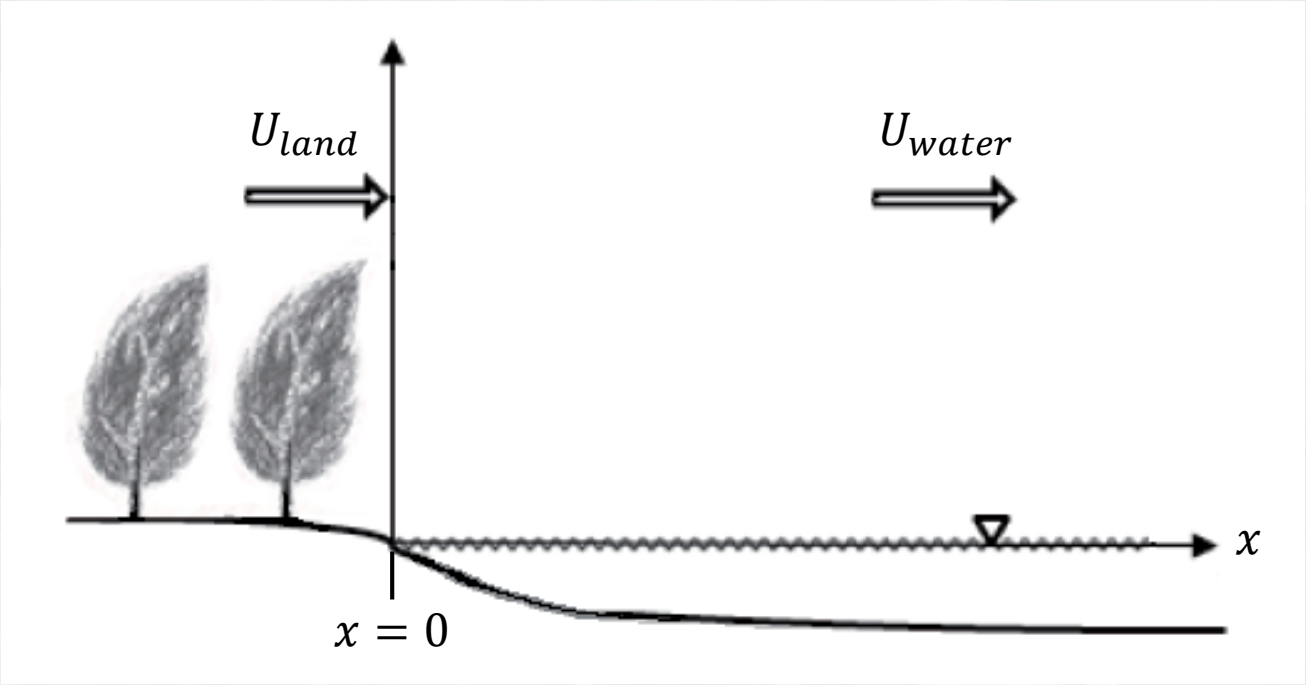


- Based on Eq.(1)
- U_{sea} at 10-m level, above MSL
- Upper bound of curve d ~ 1.6

(Schwab and Morton, 1984)

Simple 1-D Model of Over-Water Wind Speed Based on Data at Upwind Weather Station(s)

Basic Governing Eq. assuming there is linear relation between $\frac{dU}{dx}$ and U, the over-water wind speed along distance x.



1-D Governing Eq. & BCs

1-D Governing Eq. $\frac{dU^*}{dx^*} = \frac{a - U^*}{b}$

where $U^* = \frac{U}{U_l}$ (≥ 0) is the dimensionless over-water wind speed

$U_l = U\ (x = 0)$ is the wind speed at land-water boundary

$x^* = \frac{x}{x_L}$ (≥ 0) is the dimensionless distance over water surface

x_L is an upwind characteristic land range

$a, b\ (> 0)$ are dimensionless parameters

Boundary Conditions

BC1: $U^* = 1$ or $U = U_l$ @ $x^* = 0$ or $x = 0$

BC2: $U^* = U^{*,c}$ or $U = U^c$ @ $x^* = \infty$ or $x = \infty$

where $U^c \sim 1.6\, U_l$ is given as the upper bound of U

Solution of 1-D Over-Water Wind Speed

General Solution: $U^* = a - b \cdot \exp(\frac{c - x^*}{b})$, where c ($< x^*$) is a constant

Use BC2, $U^* = U^{*,c}$ @ $x = \infty$, we can get $a = U^{*,c}$

Then, the solution becomes $U^* = U^{*,c} - b \cdot \exp(\frac{c - x^*}{b})$

Let $c = 0$ for a particular solution, $U^* = U^{*,c} - b \cdot \exp(\frac{-x^*}{b})$

Use BC1, $U^* = 1$ @ $x^* = 0$, we can get $b = U^{*,c} - 1 = (U^c - U_l) / U_l$

Therefore, the final solution is $U^* = U^{*,c} - (U^{*,c} - 1) \cdot \exp(\frac{-x^*}{b})$

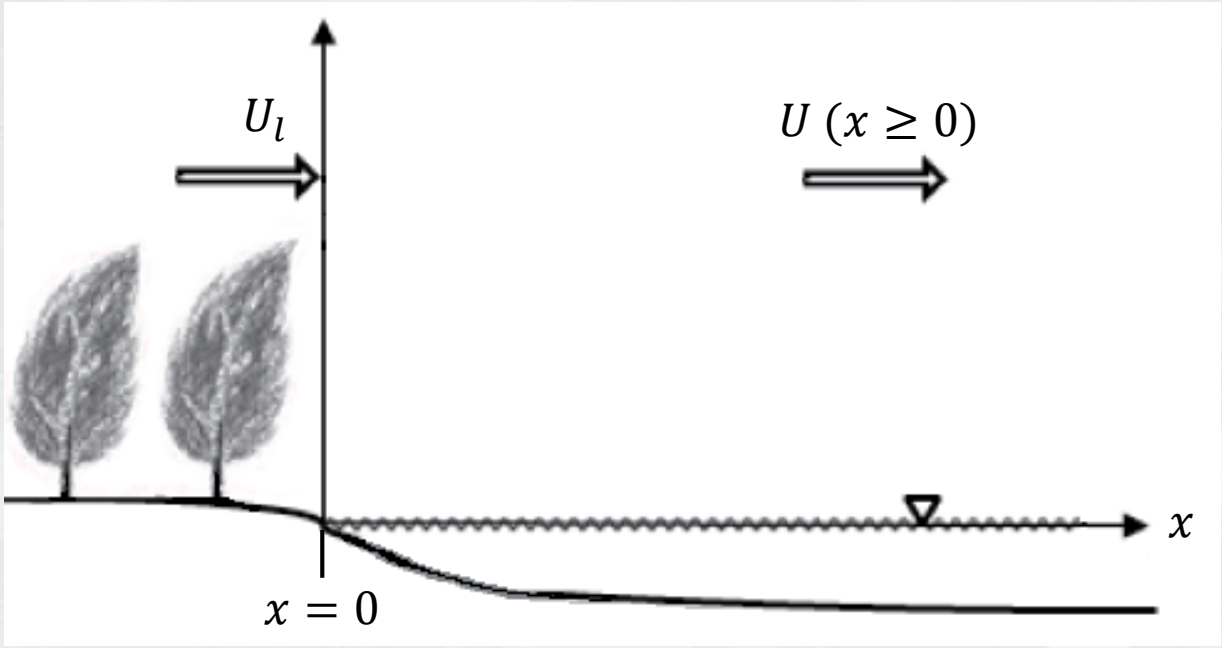
or $U = U^c - (U^c - U_l)/\exp(\frac{U_l}{U^c - U_l} \cdot \frac{x}{x_L})$

Final Solution Form

Assume $U^c(\mathrm{m/sec}) = 1.62 + 1.17\ U_l(\mathrm{m/sec})$ based on Hsu (1985),

the final solution form is

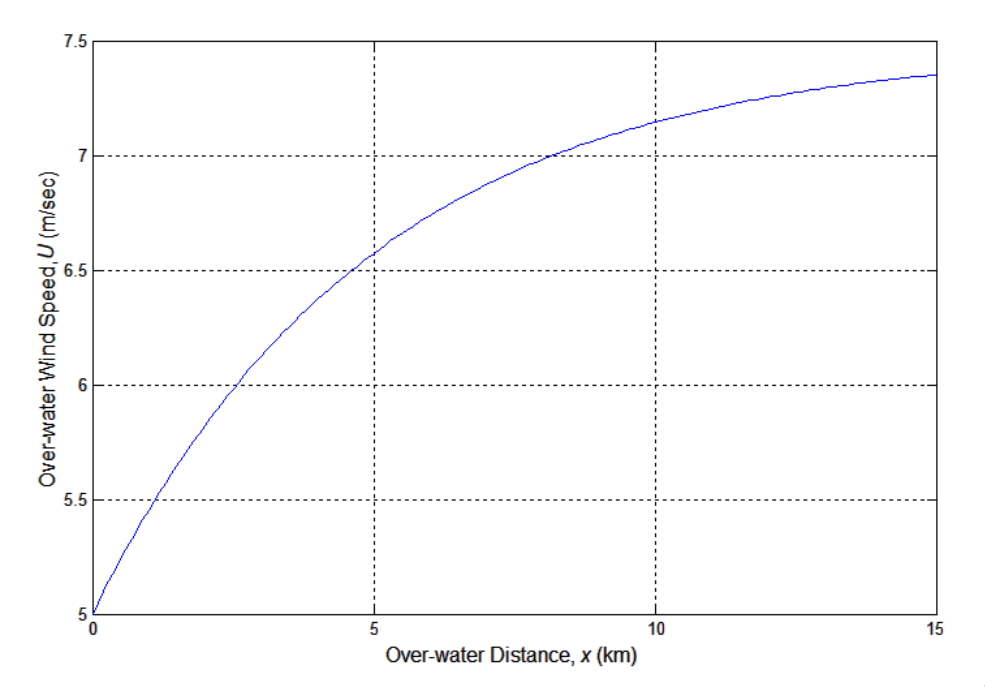
$$U\ (\mathrm{m/sec}) = 1.62 + 1.17\ U_l - (1.62 + 0.17\ U_l)/\exp\left(\frac{U_l}{1.62 + 0.17\ U_l} \cdot \frac{x}{x_L}\right)$$



An idealized 1-D Example

x_L , an upwind characteristic land range
= distance of semi-constant upwind over (or across) land surface
(initially given as 10 km on land boundary in the model)

For example, $U_l = 5\ \mathrm{m/sec}$, we will have $U^c = 7.5\ m/sec$



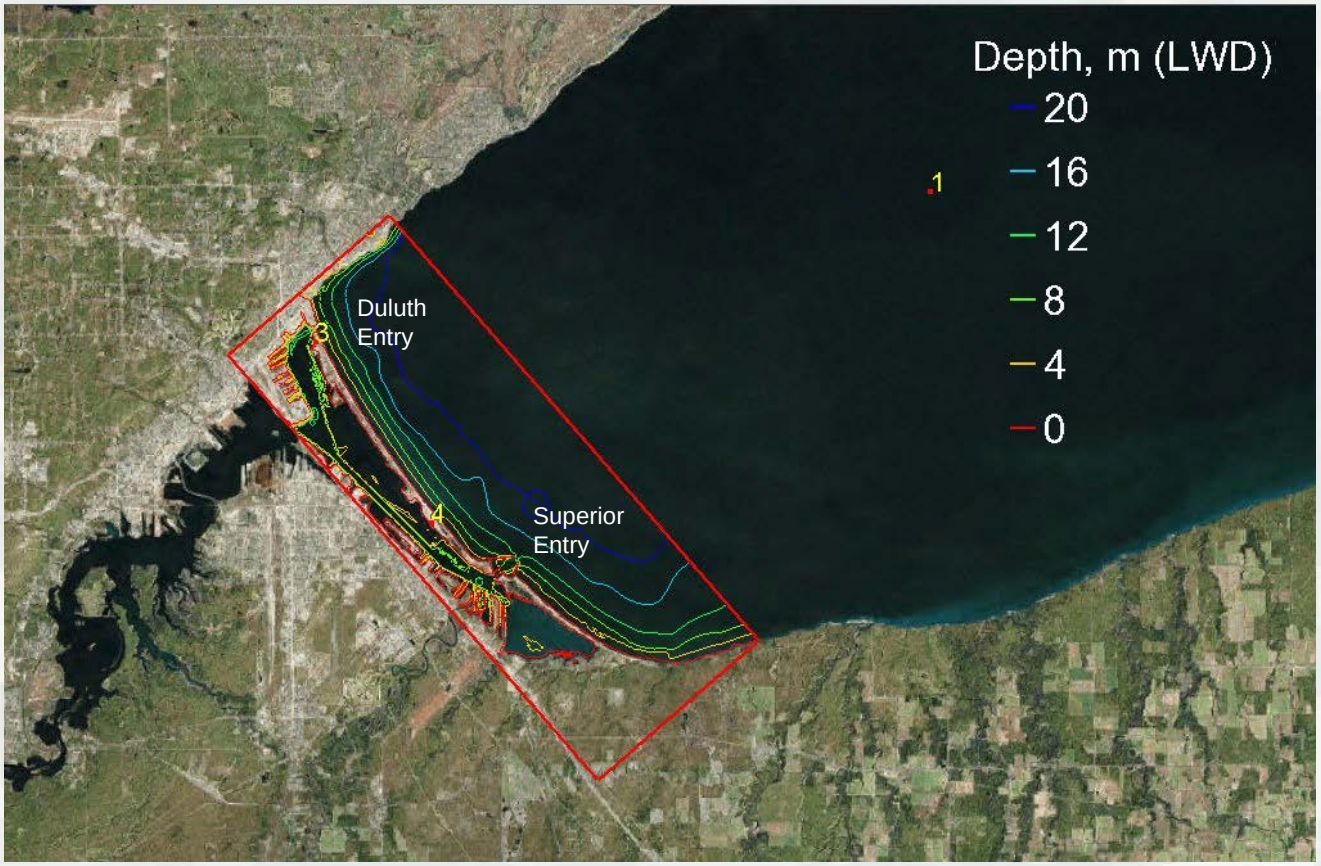
A Prototype 2-D Example: Superior Bay

Five wind stations:

1. NDBC Buoy 45028 (dep = 50 m)
2. NDBC Buoy 45006 (dep = 195 m)
3. NOAA DULM5 (Duluth, MN)
4. Duluth Airport (KDYT - Sky Harbor Airport)
5. NOAA PNGW3 (Port Wing, WI)

Red box – area of interest (Superior Bay)

Superior Bay Near-Field Wind Stations

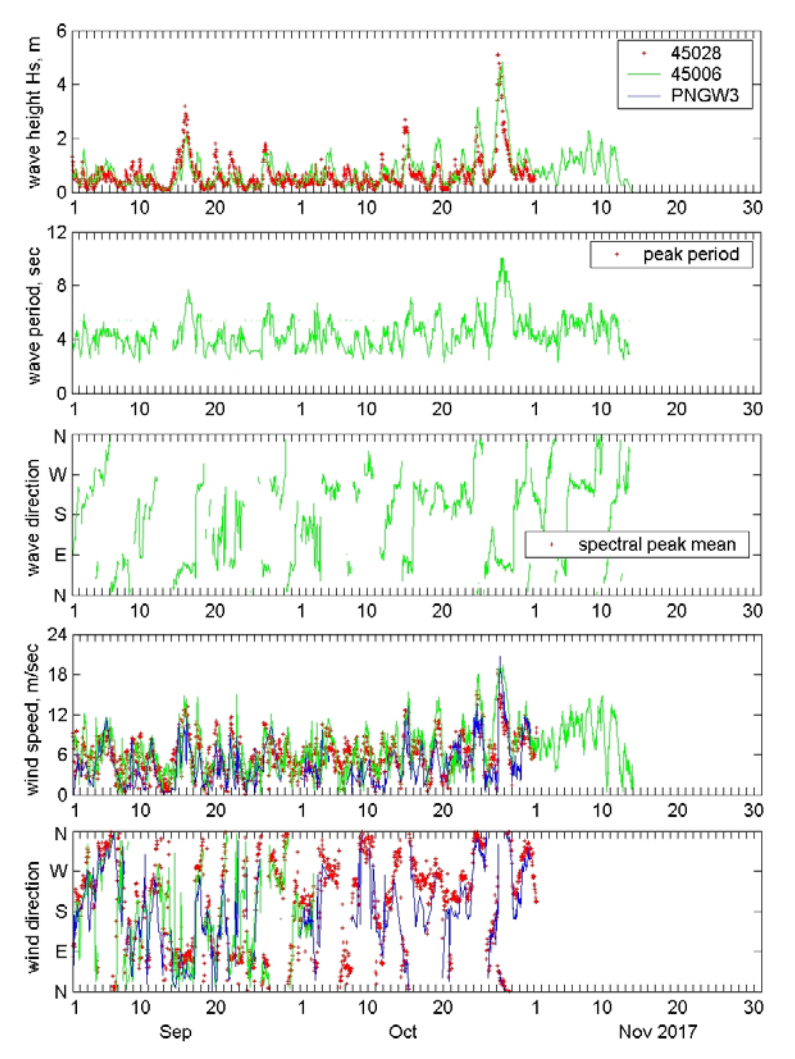


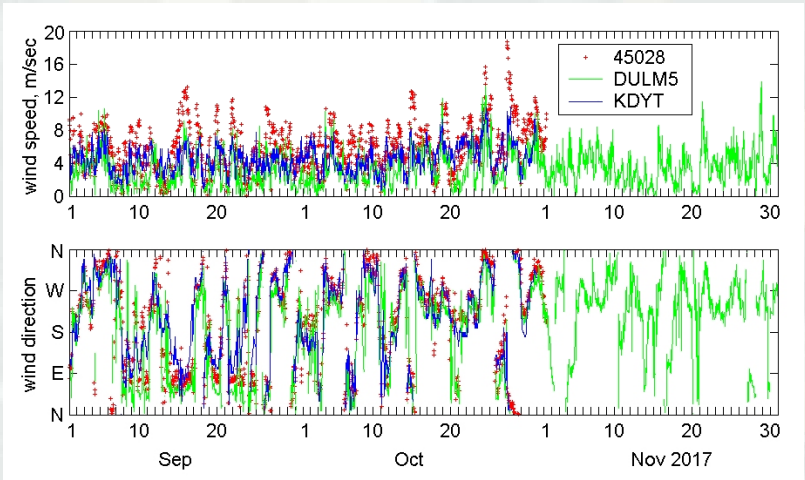
Near-field wind stations:

1. NDBC Buoy 45028 (dep = 50 m)
3. NOAA DULM5 (Duluth, MN)
4. Duluth Airport (KDYT - Sky Harbor Airport)

Red box – CMS model domain

Superior Bay Near/Far Field Wind Wave Data
September – November 2017



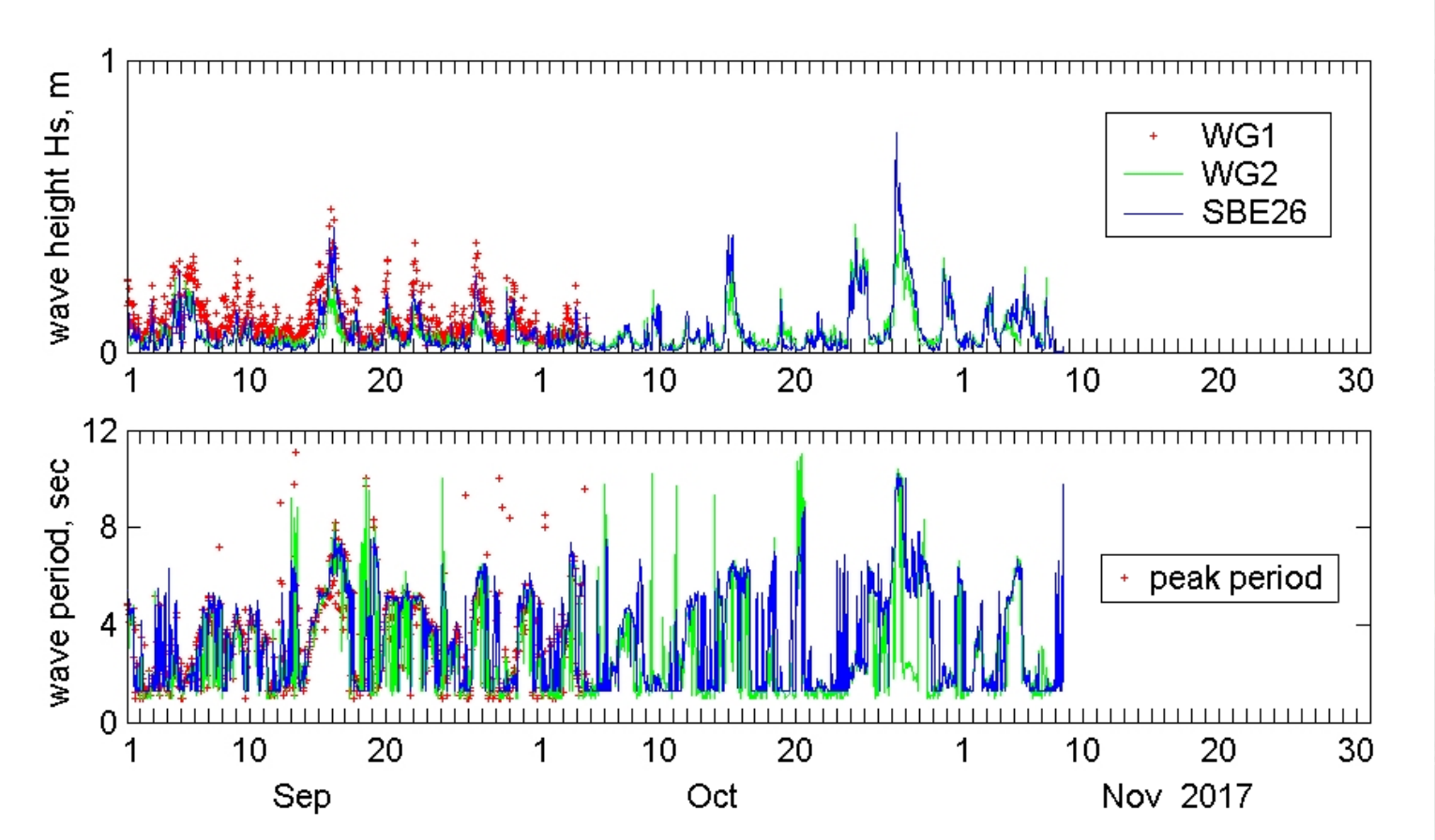


3 Wave Gauges in Superior Harbor

3 wave gauges:
(Aug – Nov 2017)

1. Wave Gauge 1
   (dep = 9 m)
2. Wave Gauge 2
   (dep = 10 m)
3. SBE26
   (dep = 2 m)

Wave Gauge Data in Superior Harbor
September – November 2017



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Apply 1-D Eq. to CMS 2-D Grid

Procedures:

1) Decompose all wind station data into CMS grid (x,y) components.

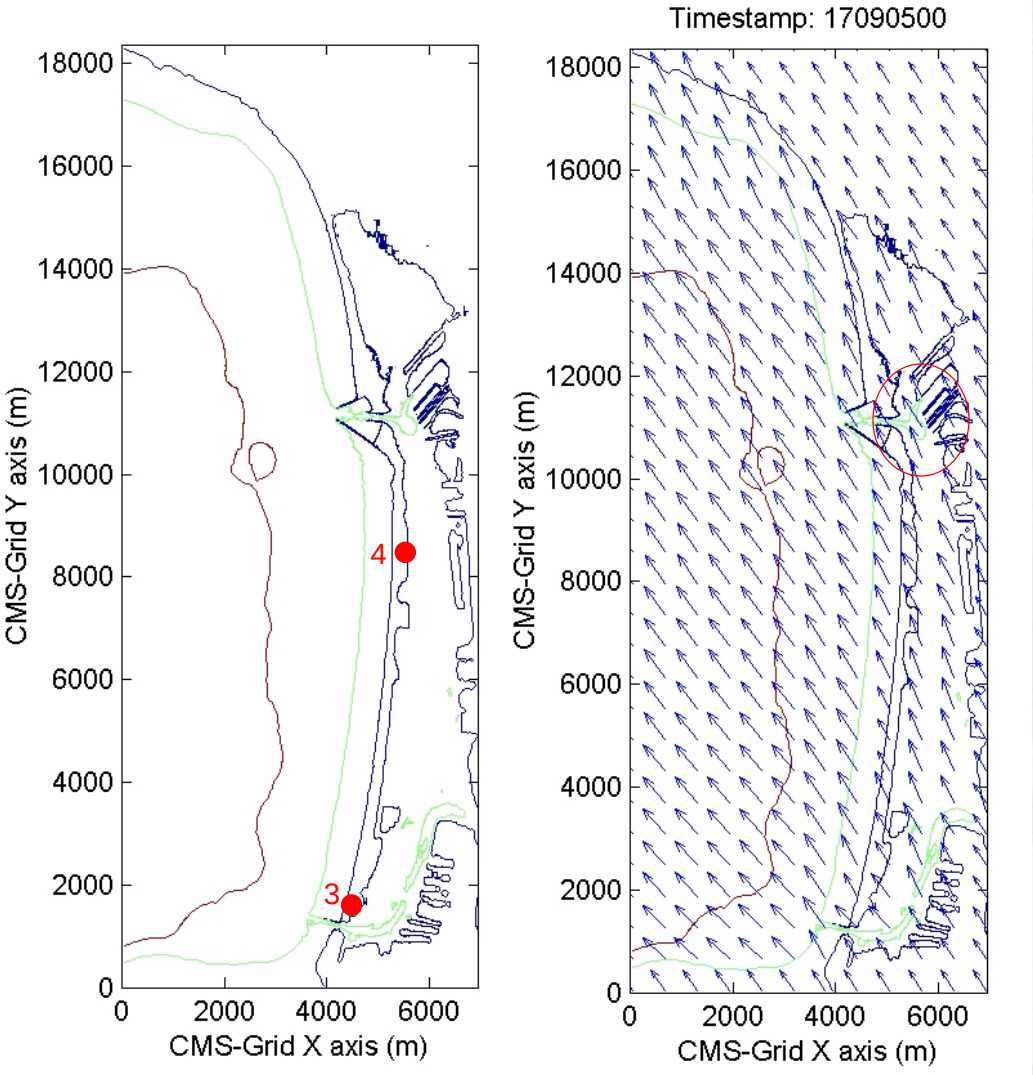
2) Assign different usage index for each wind station (0 to 5, with 0 for skipping the station data, 5 for the most usage of station data)

3) Interpolate all source wind (x,y) components into CMS grid boundary by using weights of distance between wind station and CMS grid boundary cells and the usage index of wind station(s)

4) For each cell on the CMS grid boundary, use the wind component normal to the boundary and pointing inward the grid domain for the 1-D over-water wind speed calculation along the row aligned with the boundary cell.

5) Sum up calculated wind (x,y) components at each cell inside CMS grid domain for the CMS modeling use.

An Example of Wind Output @ 17090500



Station No.	Station ID	Usage Index
1	45028	5
2	45006	4
3	DULM5	1
4	KDYT	3
5	PNGW3	0