Influences Of Wave Climate And Sea Level On Shoreline Erosion Rates In The Maryland Chesapeake Bay

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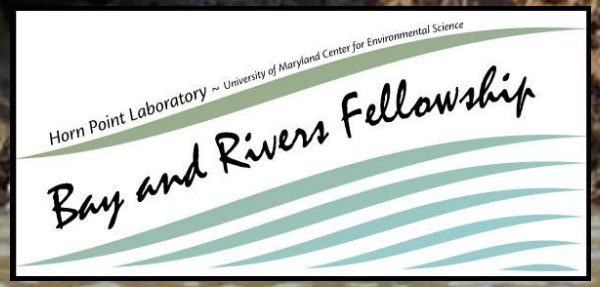


Comprehensive Dataset

(1) Observational Data:

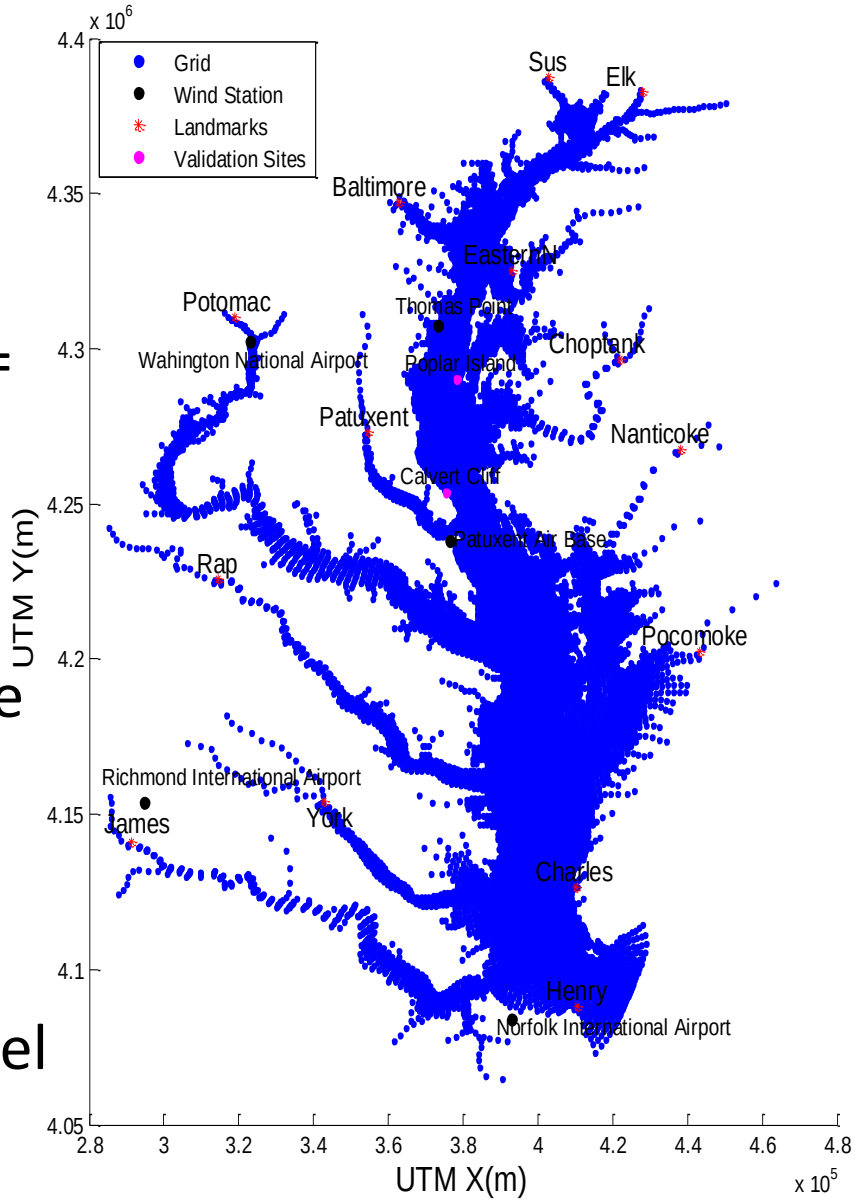
- Erosion rates (Coastal Atlas, Maryland DNR);
- Coastal Morphology (Maryland Geological Survey; CB Shoreline Inventories, VIMS)
- Wind: interpolated from 5 wind stations following USEPA Chesapeake Bay Program (CBP) protocols from 1985 to 2005

(2) Model :

- Sea level: Validated Output of CBP Hydrodynamic model (Cerco 2000) from Army Corp of Engineers
- Wave climate: Implement and compare Simulating WAve Nearshore (SWAN) and the USEPA CBP wave model (Kim, unpublished)

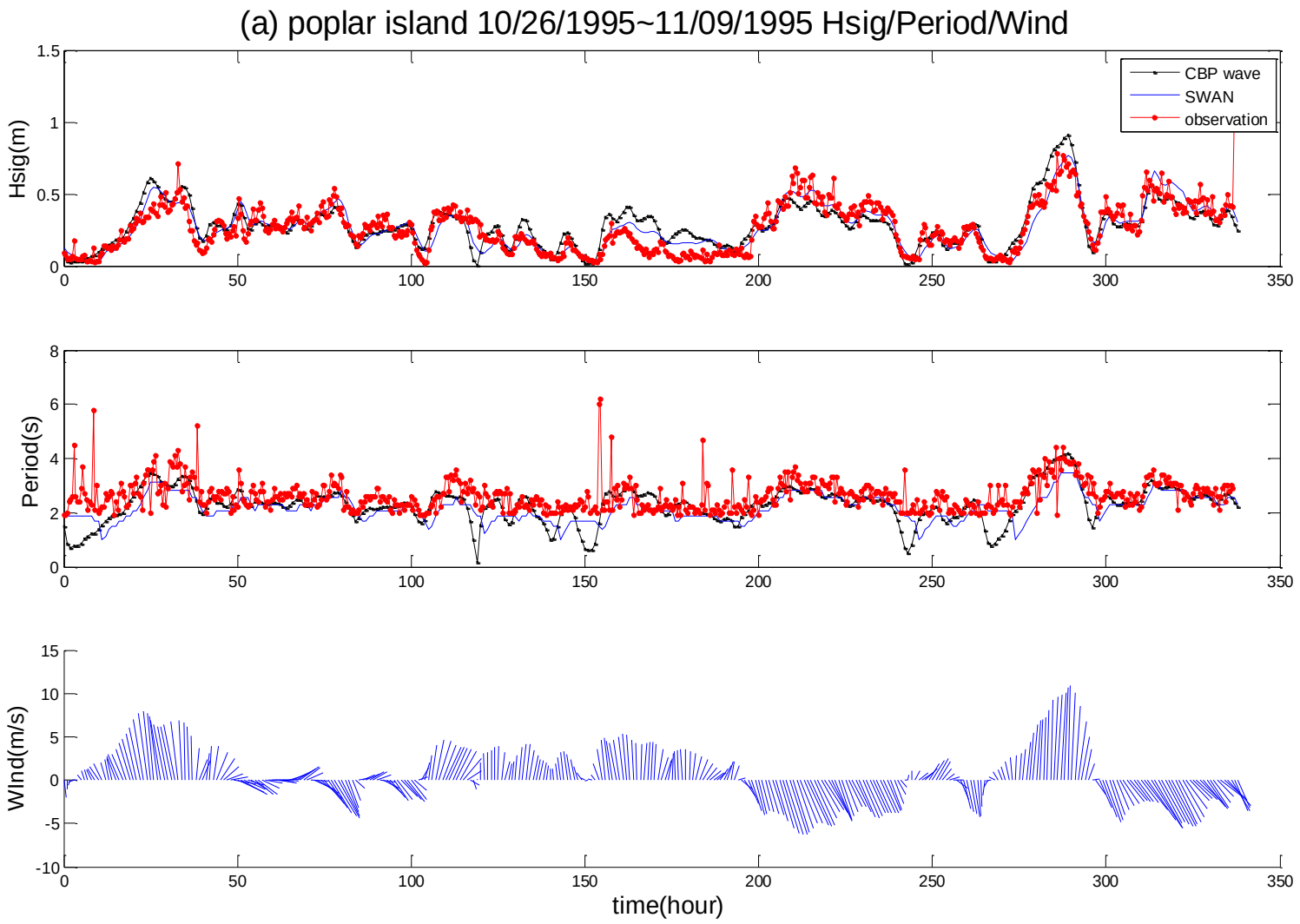
Numerical Models Configurations :

- Grid: curvilinear 282*178, 1km(axial)*0.4km(lateral)
- Input: Bathymetry, Wind
- Boundary (SWAN): Wave height= 0 and Period = 0.1 at ocean boundary (no swell); Boundary(Hydrodynamic): observations at ocean boundary
- Output (CBP wave): Period, Wave Height, Fetch
- Output (SWAN):Period, Wave height, Max-Bottom Orbital Velocity, Wave Power
- Output (Hydrodynamic): Sea Level

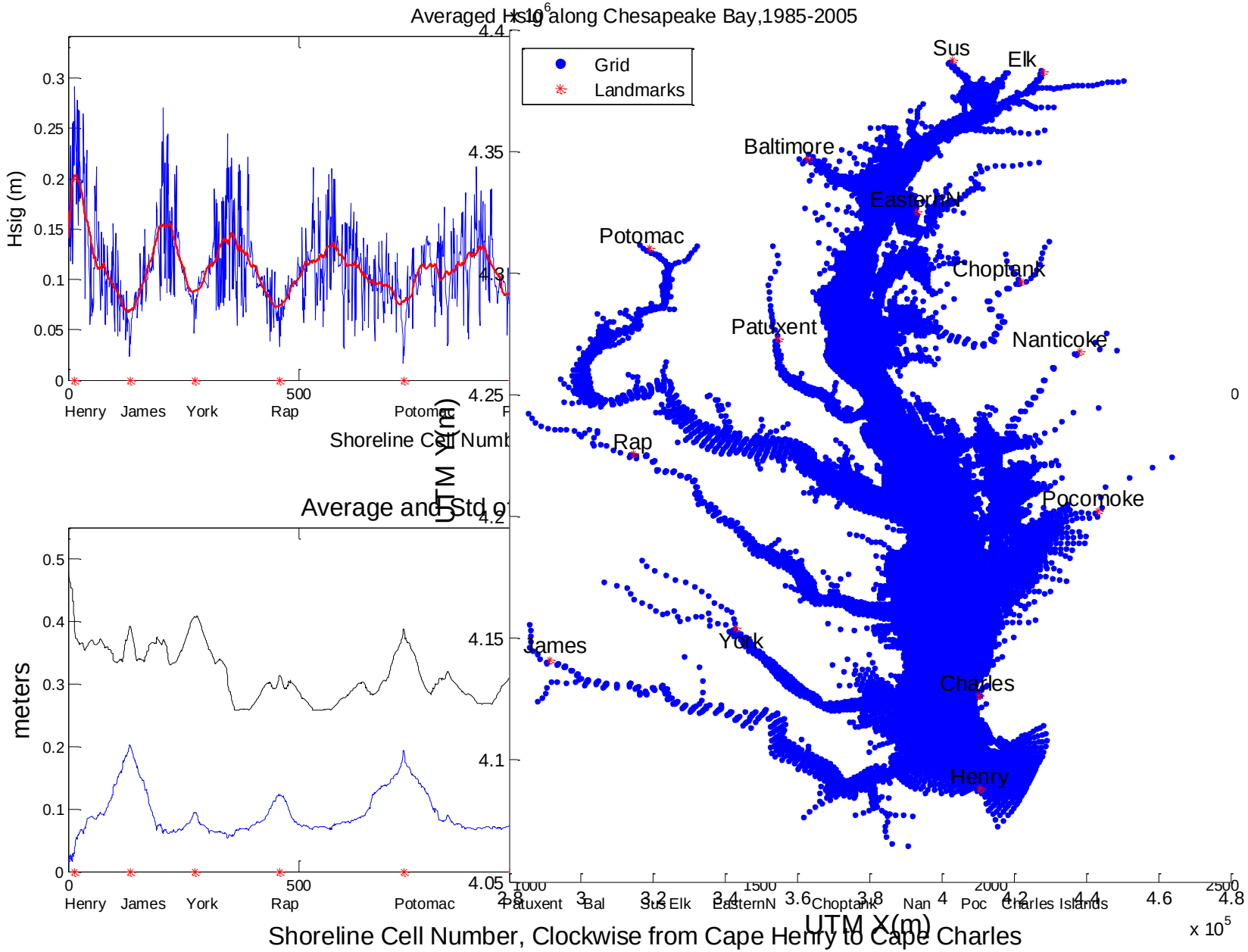


Numerical models:

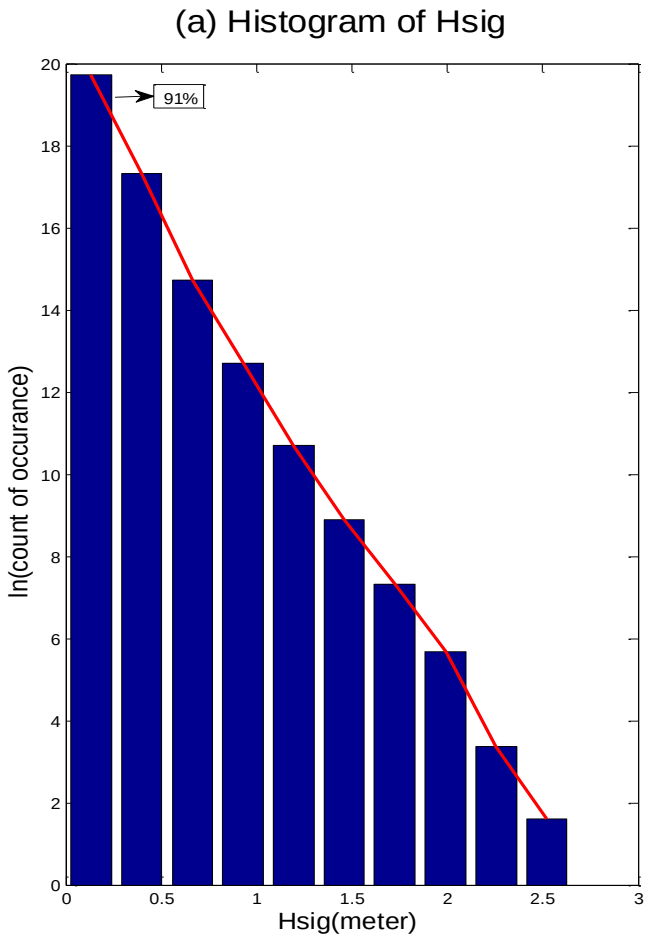
Model Validation & Comparison between CBP and SWAN

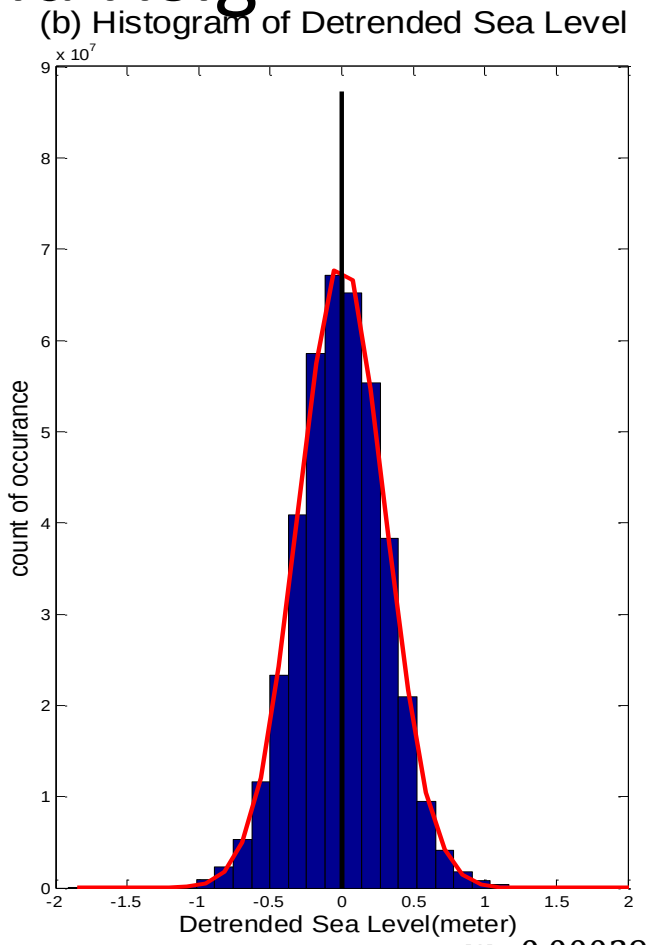


Distribution along shoreline



Probability distribution of Detrended Sea Level and Hsig





$$P(h) = 0.2495e^{-9.605h}$$

$$R^2 \approx 0.9858$$

SSE=0.00159

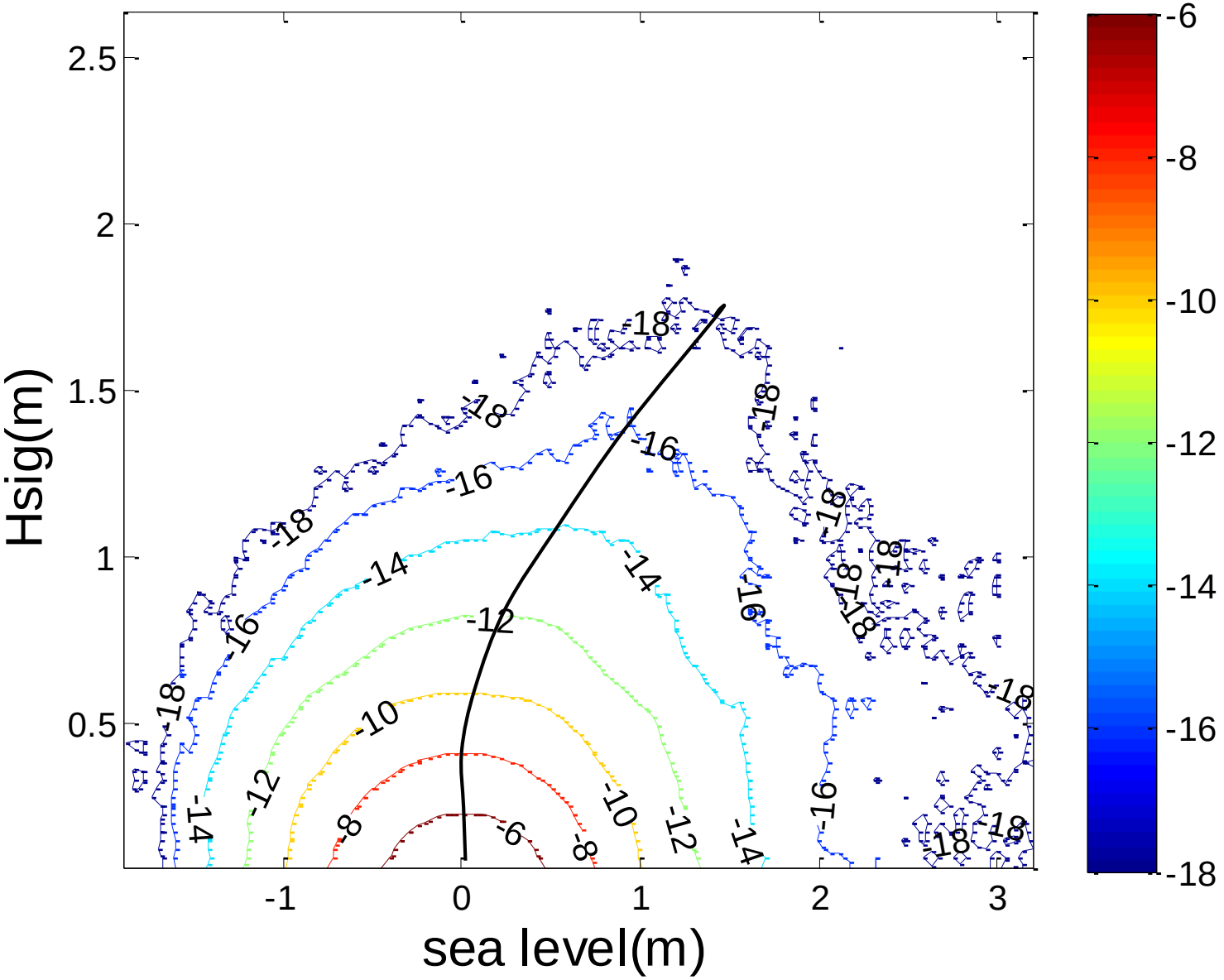
$$P(w) = 0.06783e^{-(\frac{w-0.0002914}{0.4253})^2}$$

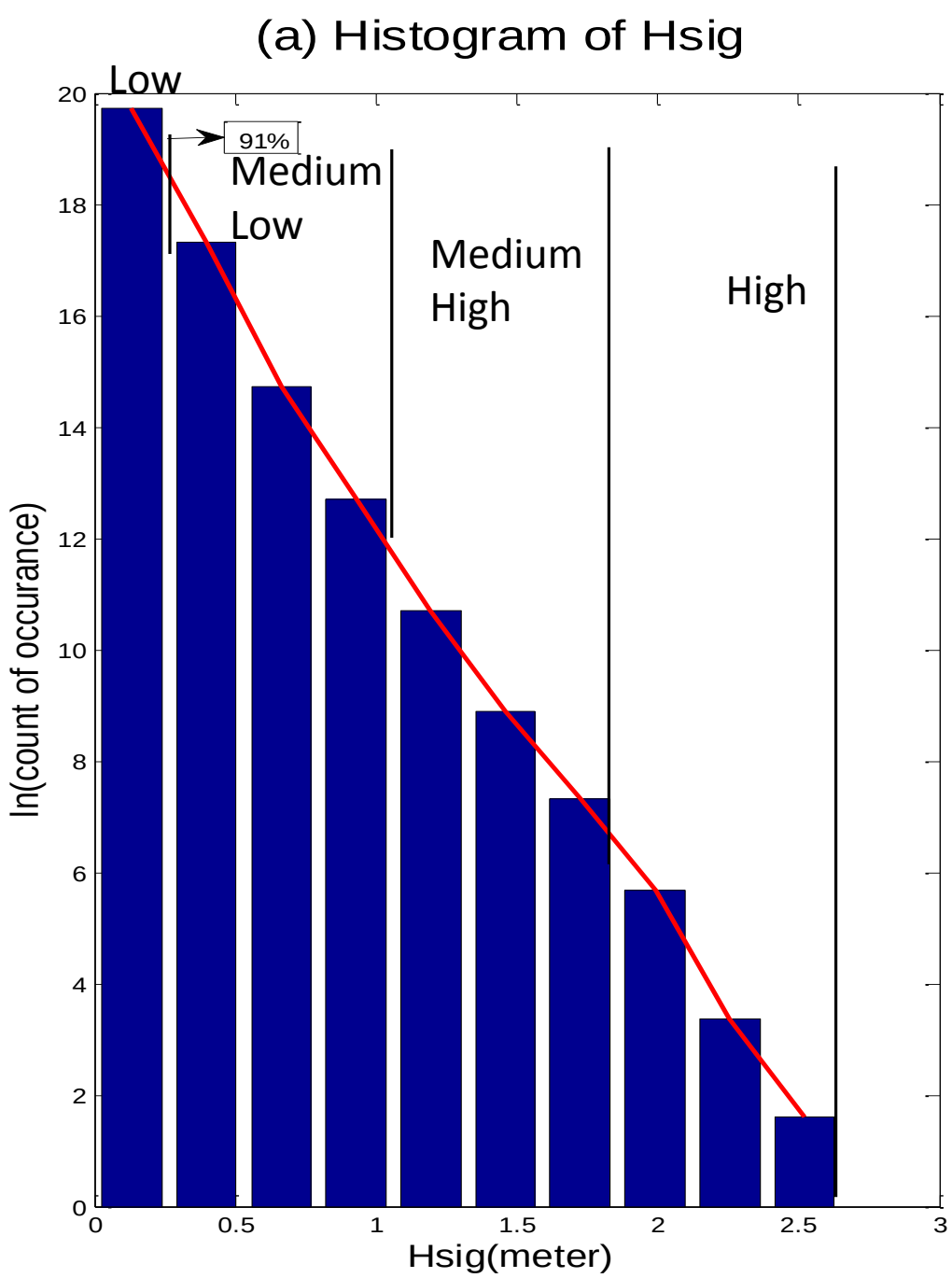
$$R^2 \approx 0.9995$$

SSE=1.932×10^{-5}

Joint probability of sea level and Hsig

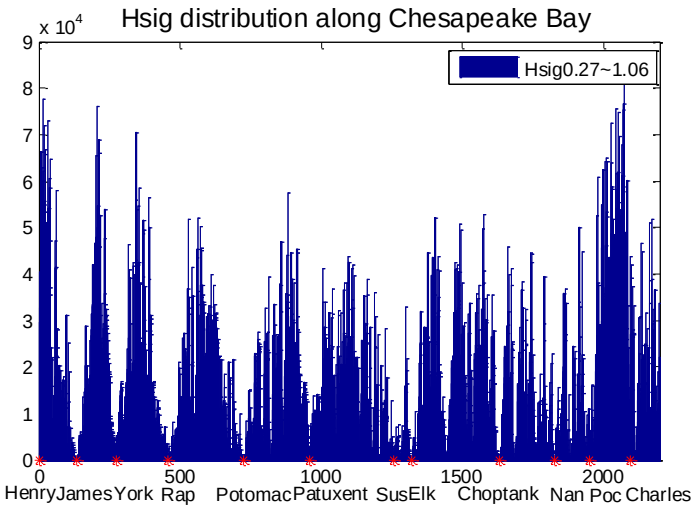
ln (Joint Probability)



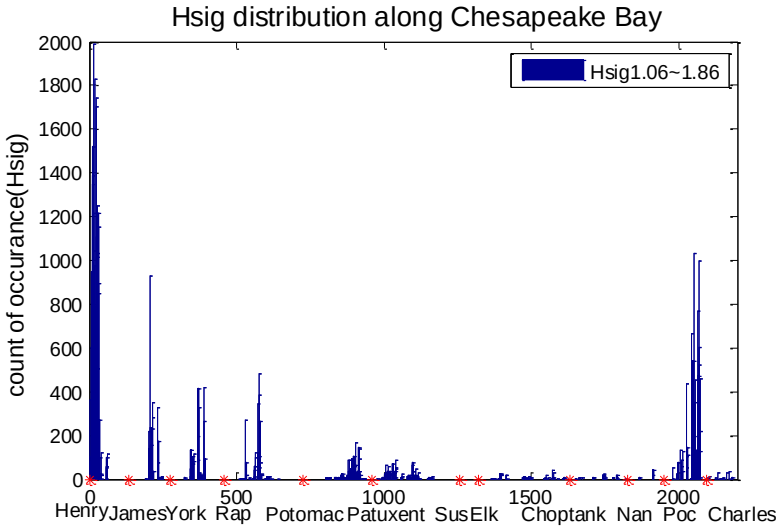

(a) Histogram of Hsig
Low
91%
Medium
Low
Medium
High
High
ln(count of occurance)
Hsig(meter)
0
2
4
6
8
10
12
14
16
18
20
0
0.5
1
1.5
2
2.5
3

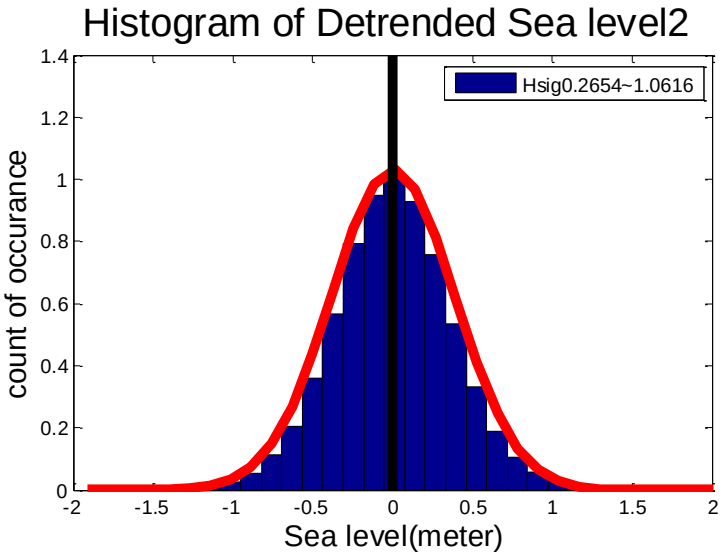
Spatial Distribution

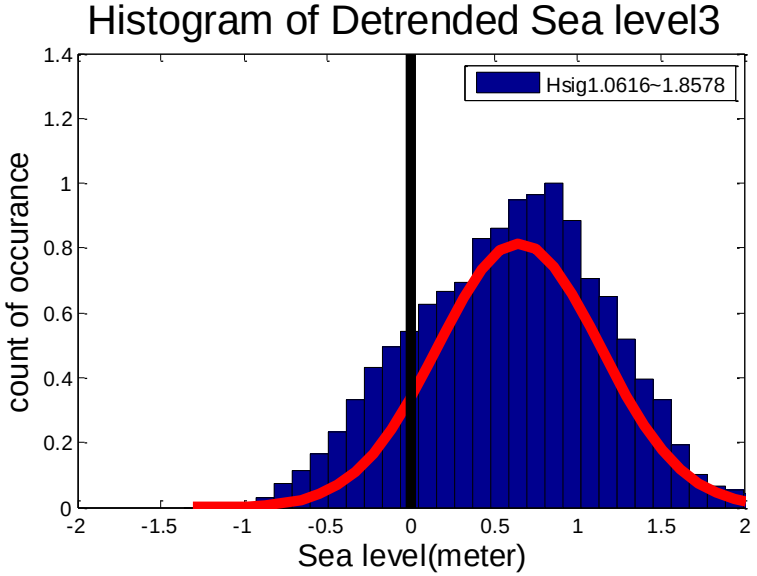
Medium Low



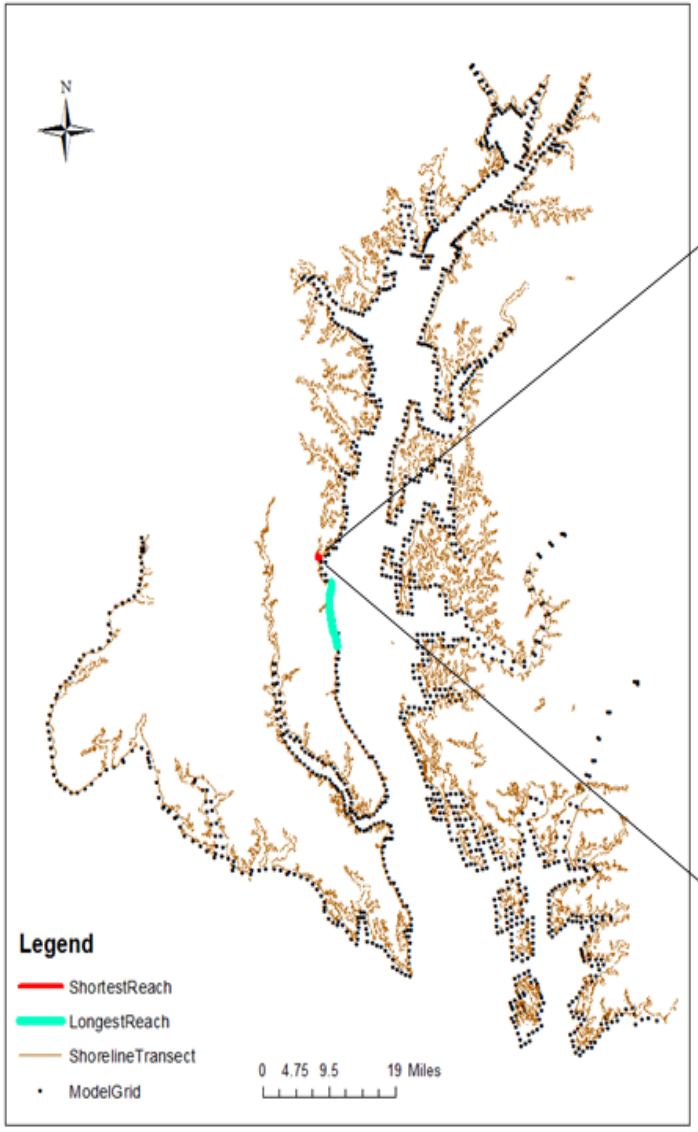
Medium High

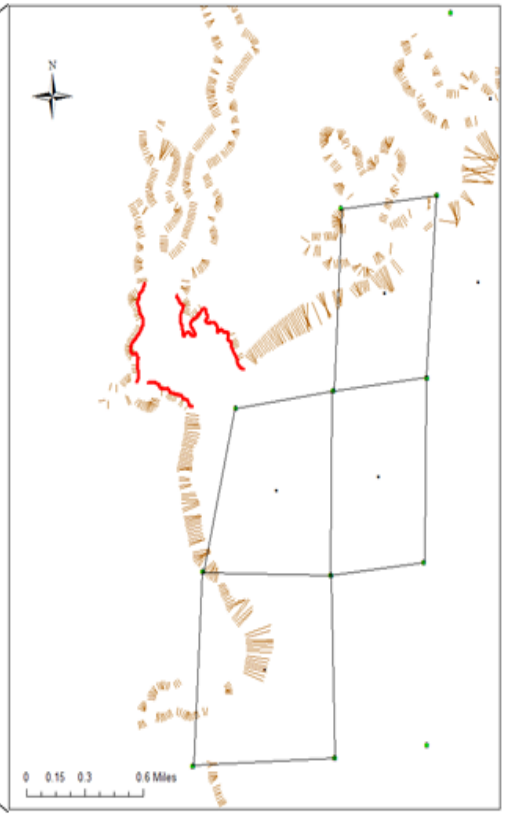






Incorporate MD shoreline datasets from 3 different scales: Transects, Model Grid, and Reach

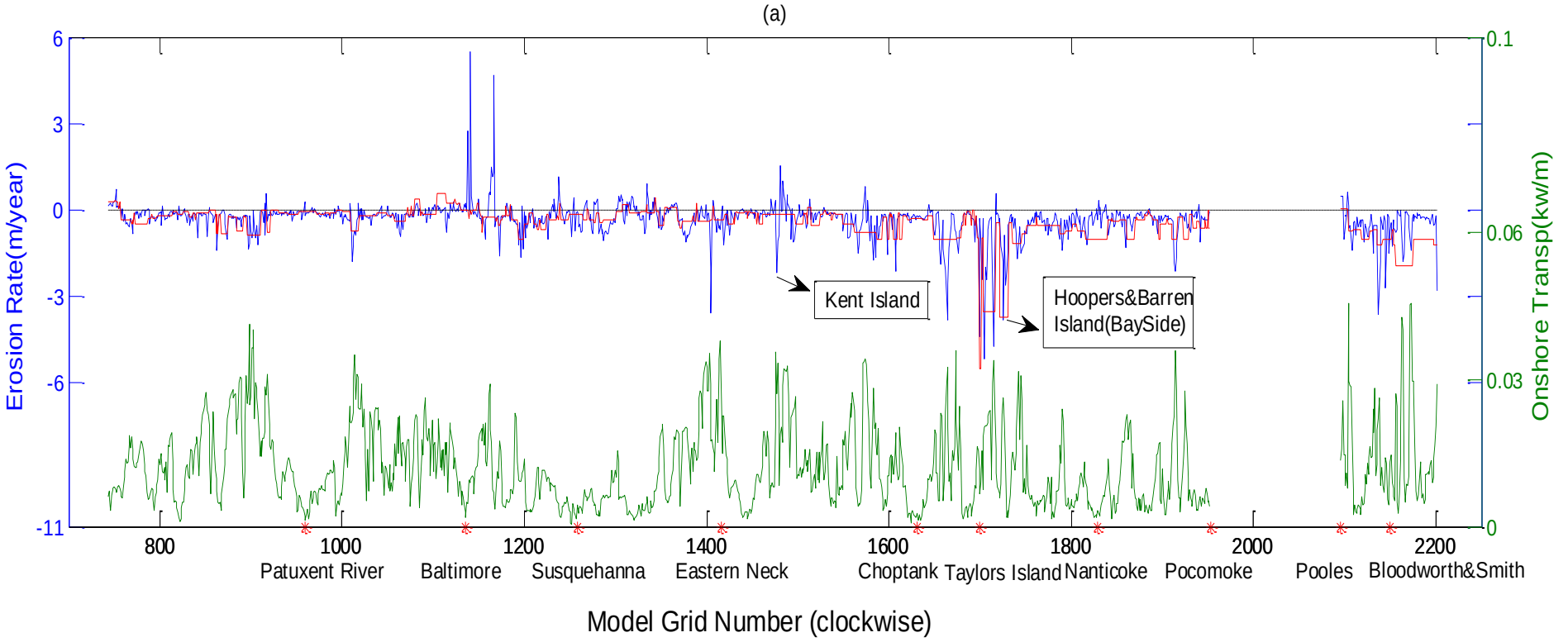




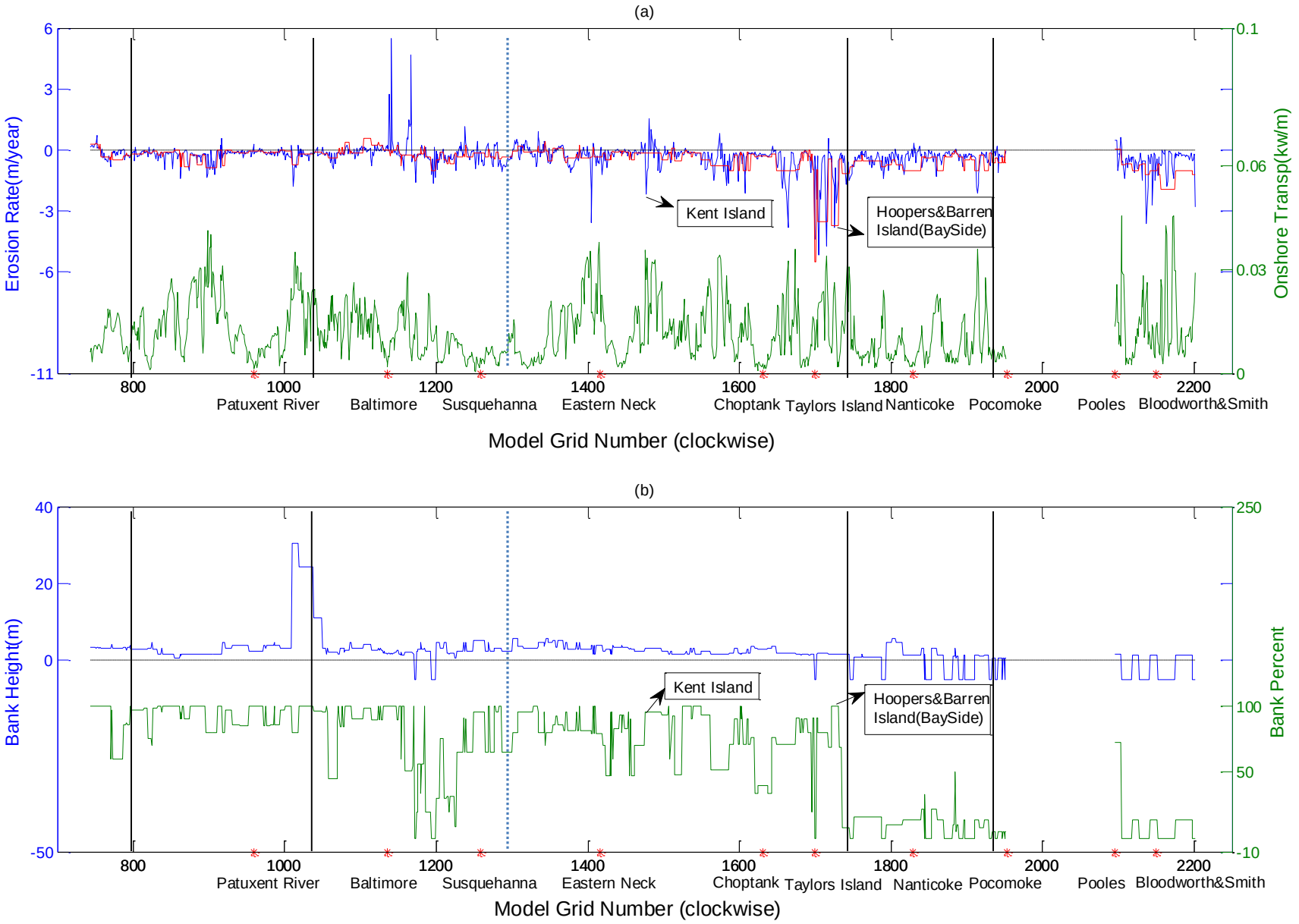
Reach:
erosion rate(unprotected); coastal morphology; sea level and wave climate.

Grid Cells(only marsh): Erosion rate; sea level and wave climate.

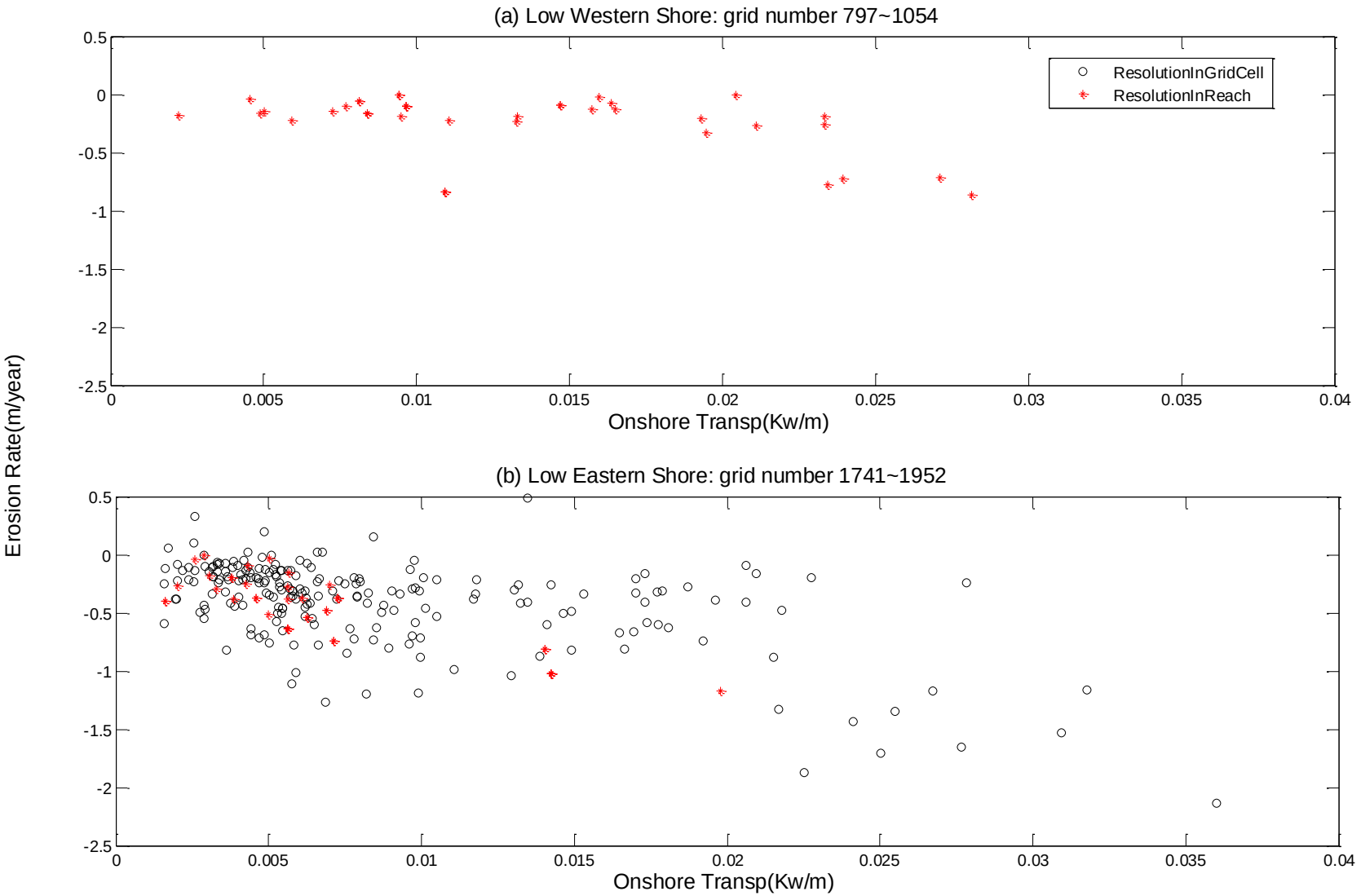
Erosion and Wave Power along MD CB



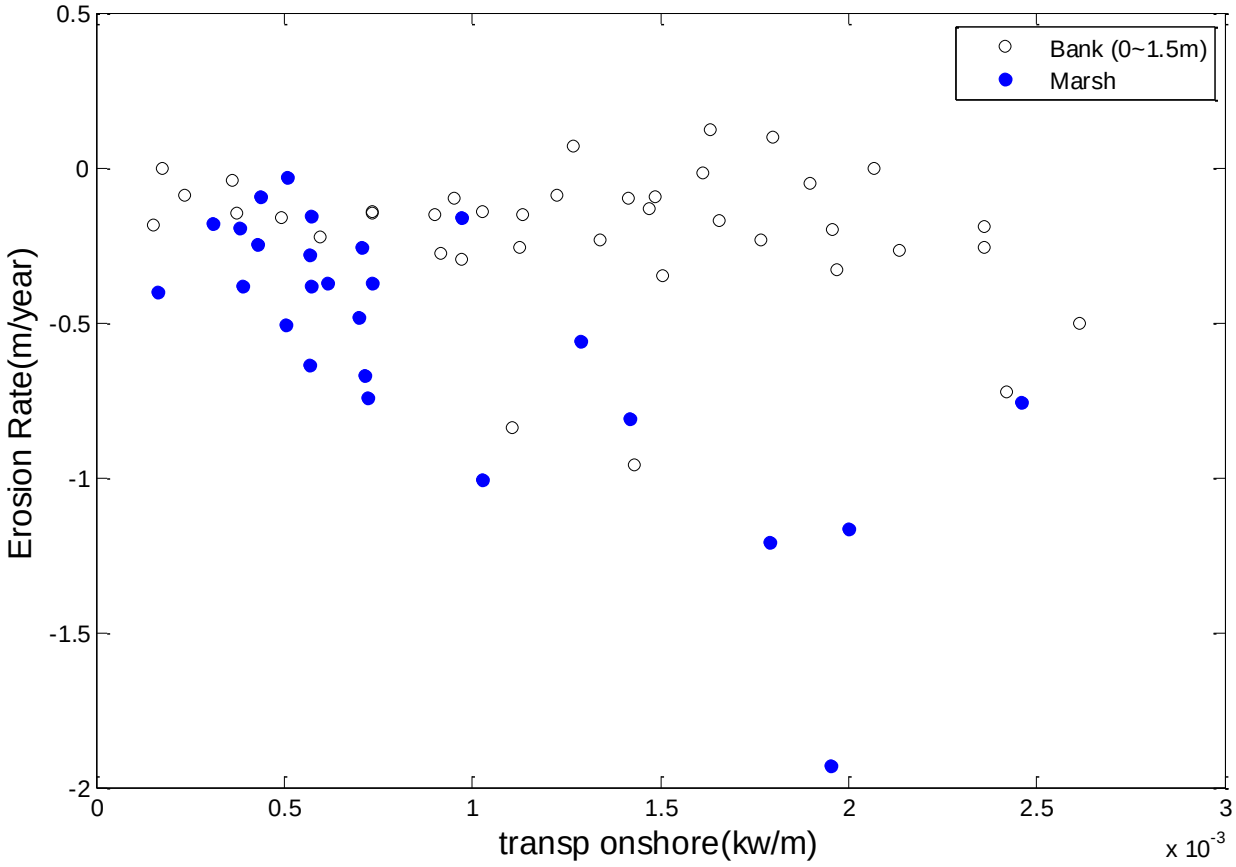
Western vs. Eastern Shore



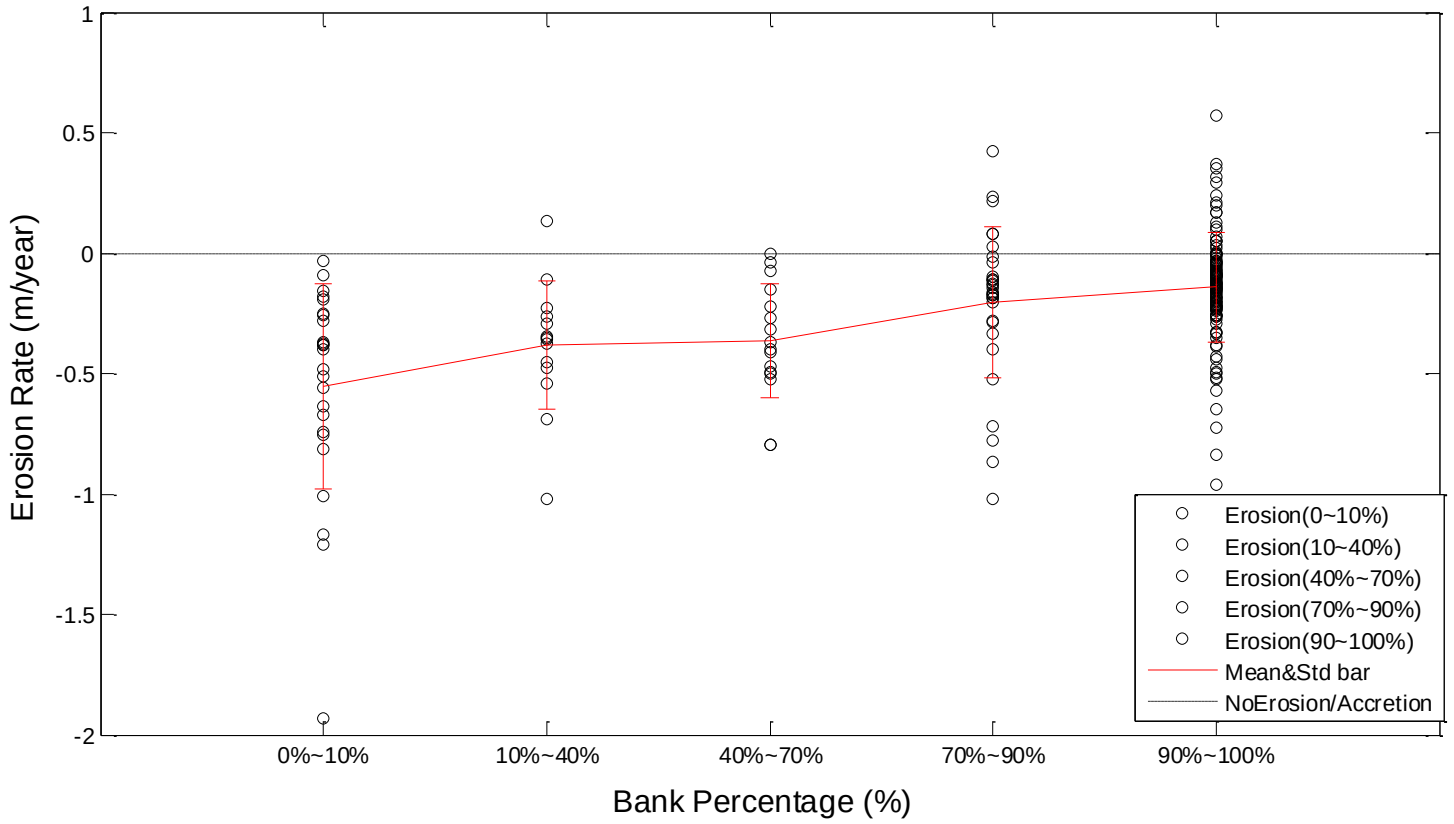
Erosion Rate vs. Onshore Wave Power: Low Bank Height



Marsh erodes much faster than bank for similar elevations



Erosion Rate vs. Bank Percentage



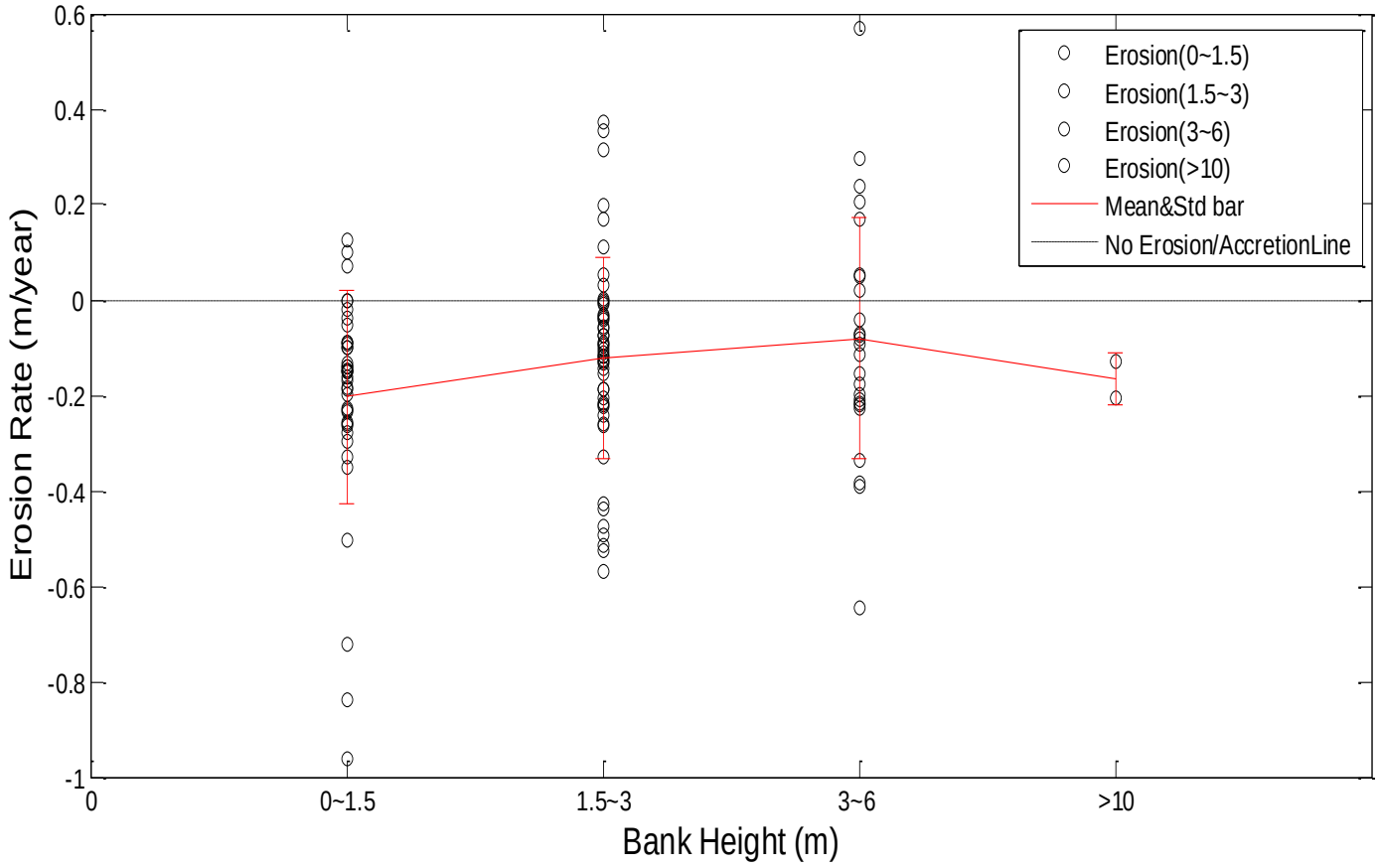
Linear Correlation: 0.44

ANOVA (99.9% statistical significance):
mean of different groups are different

Tukey's test(>95% statistical significance):
90-100% and 0-10% /10-40%/40-70%; 0-10% and 70-90%

In this study:
Bank percentage>90% defined as bank; <10% defined as marsh

Erosion Rate vs. Bank Height



ANOVA (92% statistical significance):
mean of different groups are different

Tukey's test(>99% statistical significance):
0-1.5m and 3-6m

Linear Correlation between Erosion Rate and Influential Variables

	Type	Marsh		Bank		Bank Stem	Bank Tributary	Bank Eastern	Bank Western
	Correlated Variable	Erosion	VER	Erosion	VER	Erosion			
		R>0.5, P<0.05		R>0.2, P<0.05					
	number of data/reach	26		116	115	17	99	43	73
1	Erosion	1		1	0.884	1	1	1	1
2	Hisg	-0.66							
3	Hsig90	-0.712					-0.204		
4	Hsig95	-0.721					-0.214		
5	Tps	-0.704							
6	TM01	-0.711							
7	WLEN	-0.743					-0.213		
8	FSPR	0.669		0.225			0.273	0.336	
9	LWAVP	-0.723							
10	TMBOT	-0.637							
11	URMS	-0.652		-0.227		-0.505			
12	UBOT	-0.652		-0.227		-0.505			
13	UBOTsq	-0.677		-0.256		-0.517			-0.288
14	transp_onshore	-0.745		-0.209			-0.244		-0.236
15	fetch						-0.307	-0.463	
16	Weighted fetch			-0.268			-0.28	-0.385	
17	Tidal Range	0.73		0.232			0.265		0.241
18	Bath_steepness					0.556			
19	transpall	-0.774							
20	drift						-0.226		
21	MedianWater60Hsig								0.337

More Complex Statistical Models

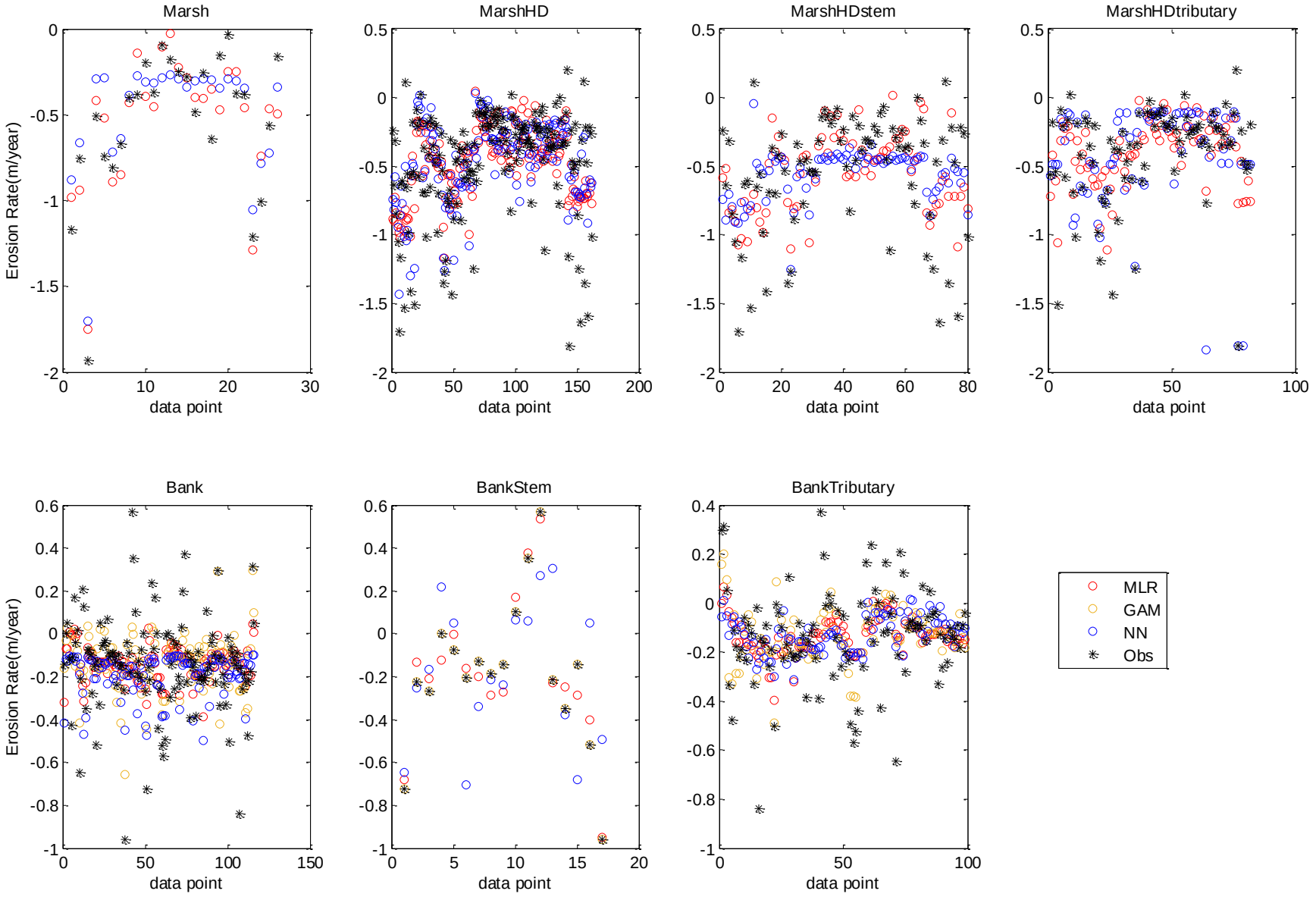
- Multiple Linear Regression(MLR)
- Generalized Additive Model(GAM)

GAM is more flexible than linear regressions and it is able to capture non-linear features.

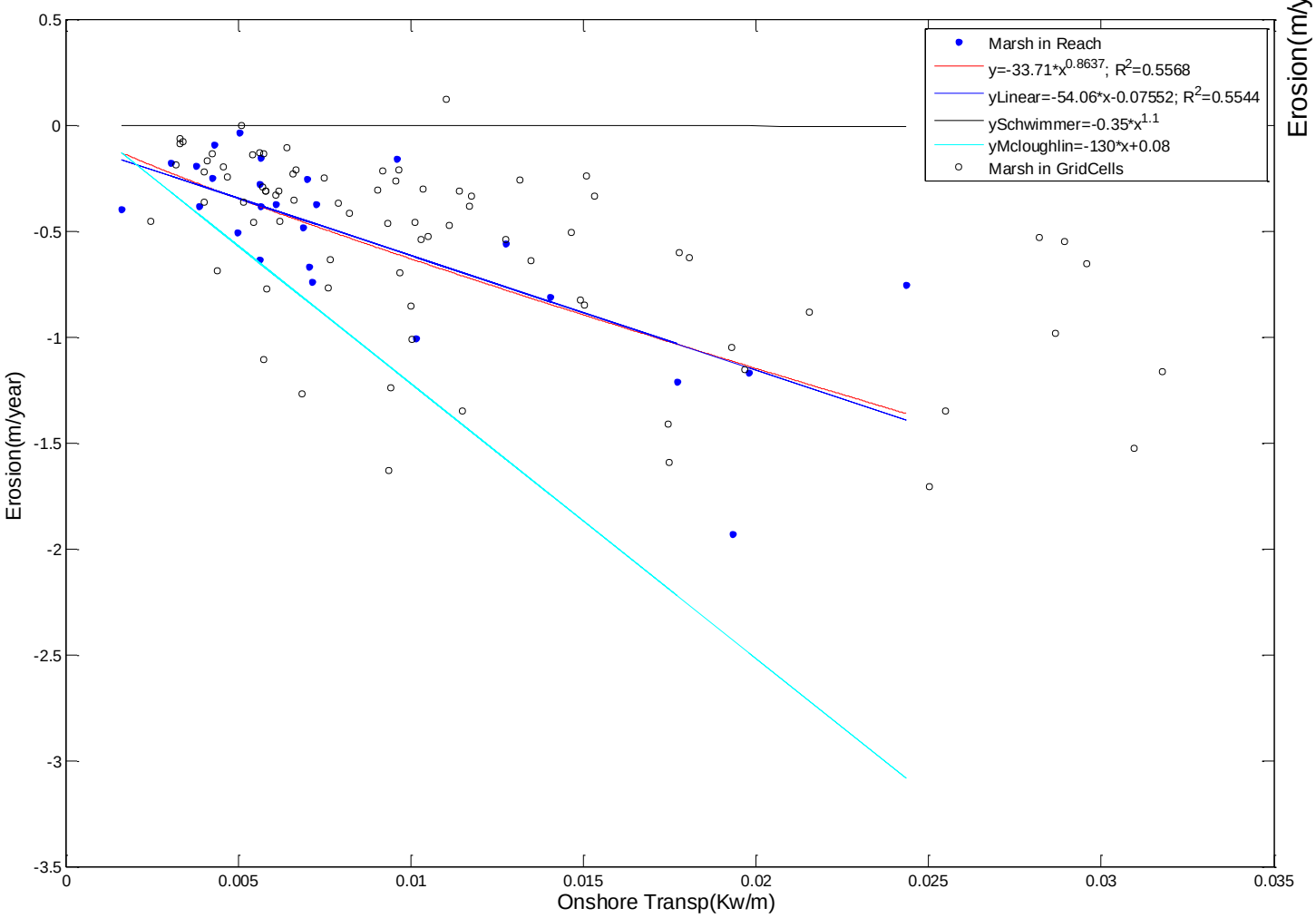
- Neural Network analysis (NN)

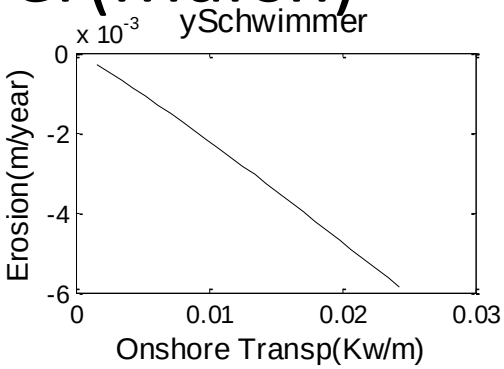
NN has the ability of representing both linear and non-linear relationships and learning these relationships directly from the data being modeled.

Statistical model results – little value added



Calculate erosion rate from wave power(Marsh)





Maryland CB(Marsh)

$$R = -33.71 \times P^{0.8637}$$

$$\mathrm{R}=-54.06 \times P-0.07552$$

Rehoboth Bay (Marsh)

$$R = 0.35P^{1.1}$$

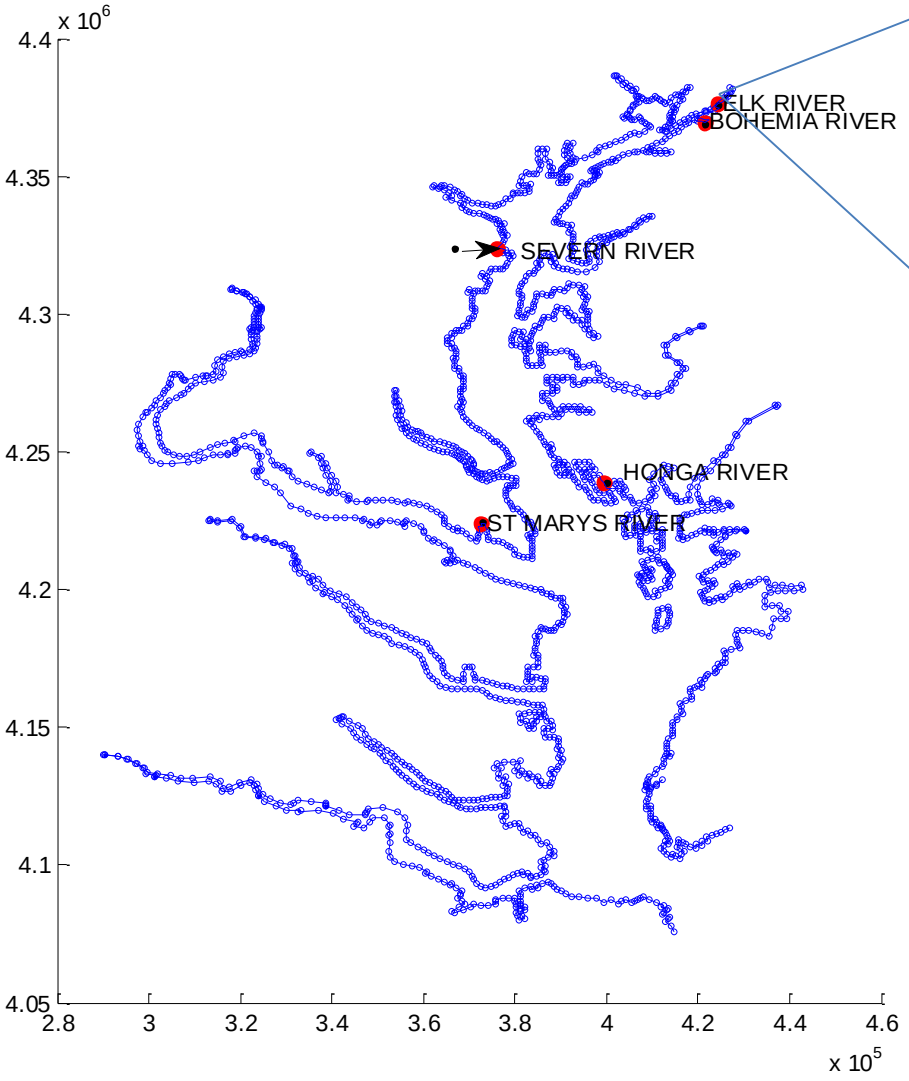
(Schwimmer,2001)

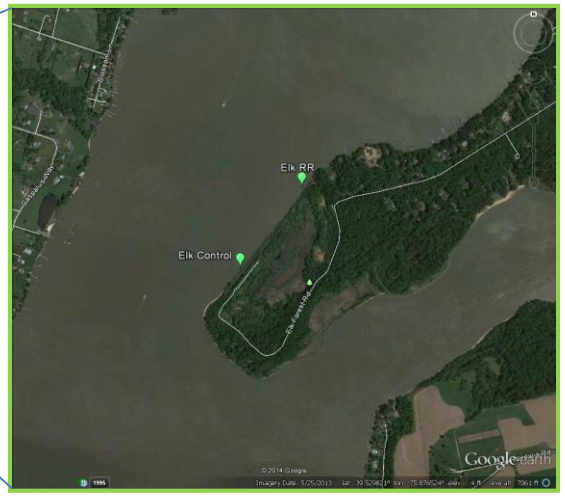
Hog Island Bay(Marsh)

$$R = -130 \times P + 0.08$$

(Mcloughlin, 2015)

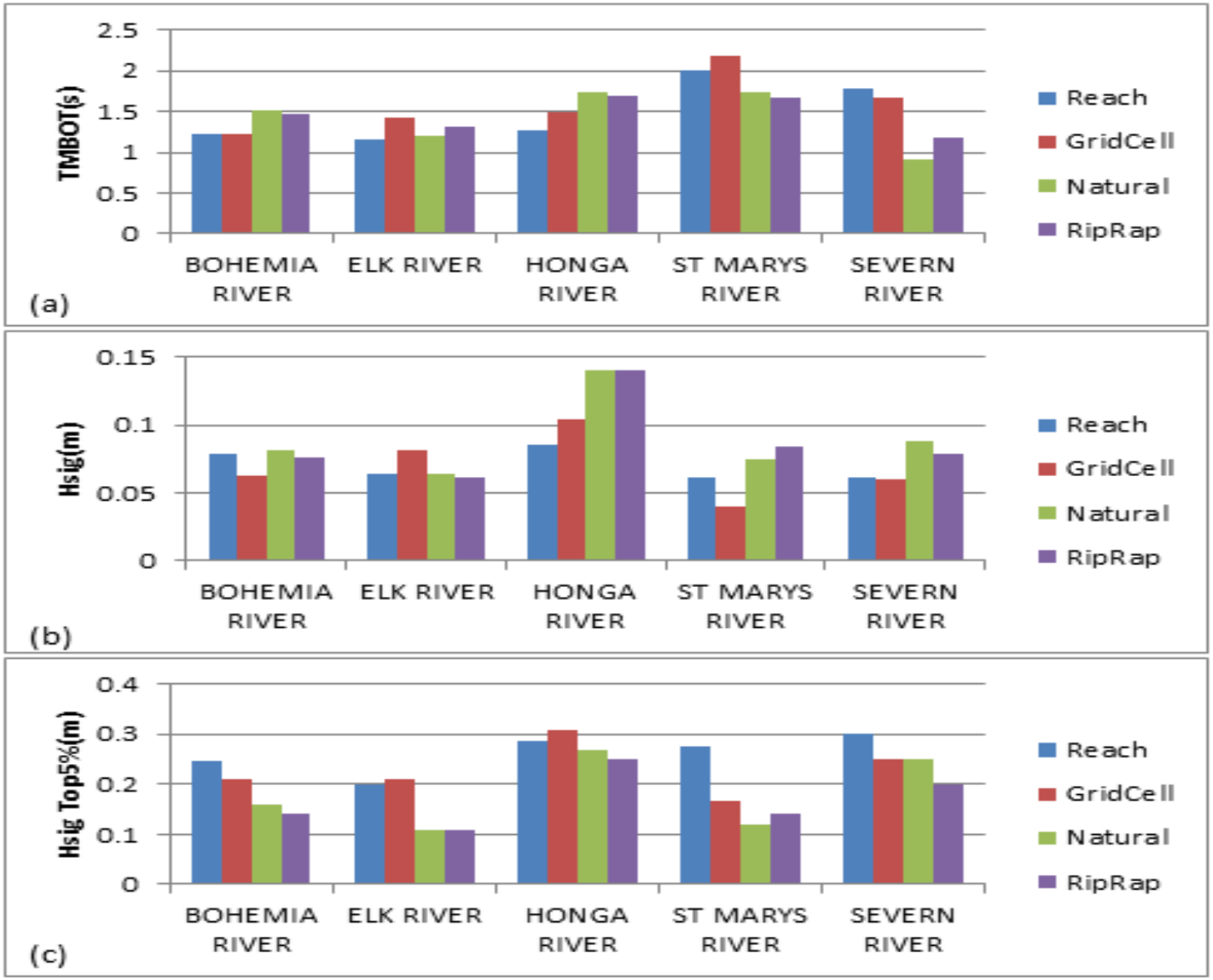
Local Scale: 5 sites



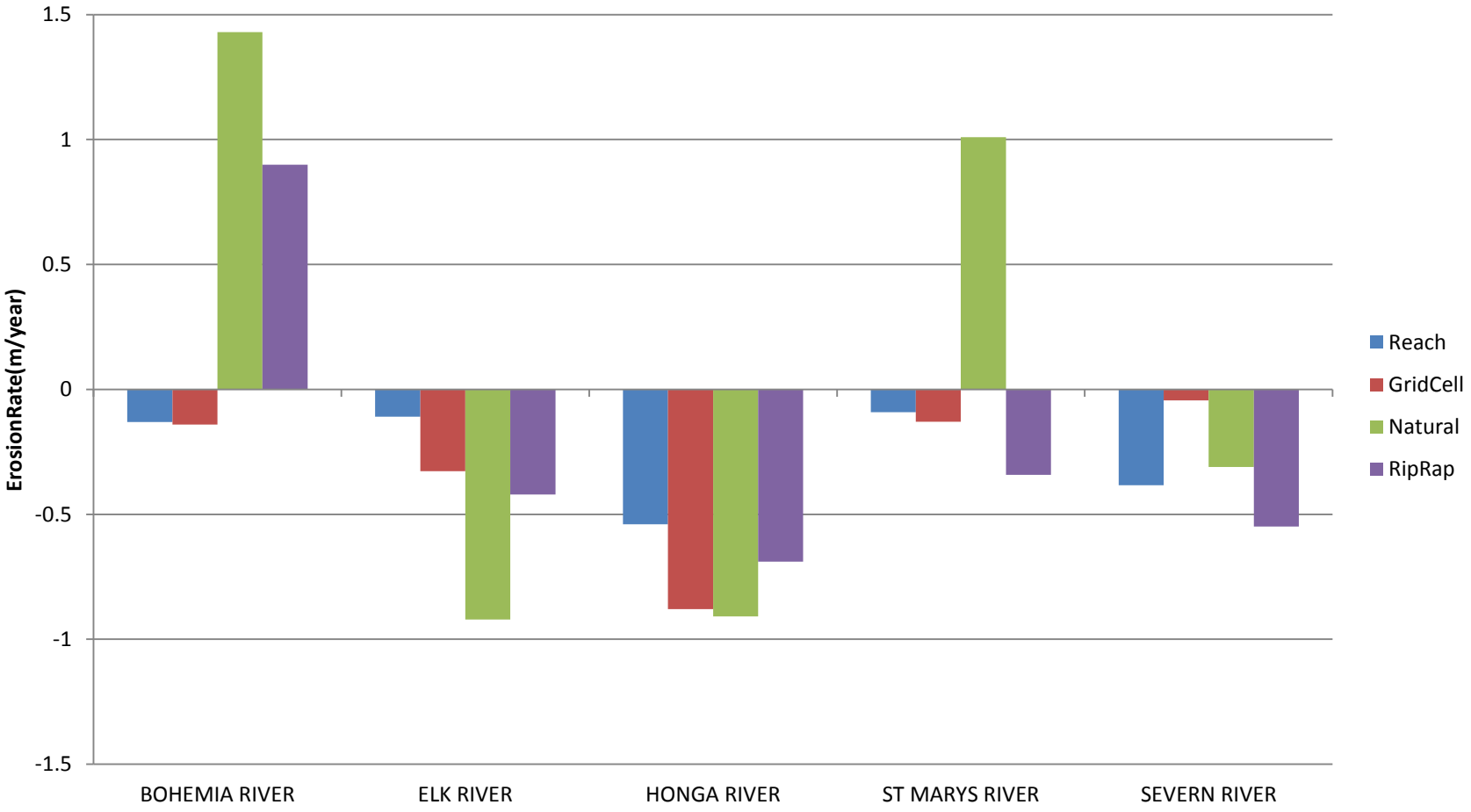


5 sites: 4~8 days summer observations using wave gauges(Koch and Booth, unpublished data)

Wave Characteristics at Different Scales



Erosion Rates at Different Scales



Conclusions

- **In CB, only considering wind generated waves, as Hsig increases, the count of occurrence of Hsig decreases exponentially. The count of occurrence of sea level follows a normal distribution.**
- **Wave climate is higher at the mouth and in the stem, especially western stem, of CB than tributaries.**
- **In CB, marsh undergoes more erosion than banks; the bay side of islands undergo the most severe erosion. Marsh also has a simpler and more significant relationship with wave climate.**
- **Wave power should be the dominant factor for shoreline erosion in Maryland CB.**
- **The results of this erosion study are applicable at corresponding scales, such as grid cells and reach.**
- **Performances of complex statistical models will very likely improve with a higher resolution and more comprehensive dataset. This dataset will also be needed for building reliable erosion rate prediction models.**

How to use this information?

Marani et al. (2011) analysis of marsh erosion in Venice Lagoon

$$Eh\rho_{dry} = \alpha Pf(\frac{h}{d})$$

mass erosion rate of bank =

empirical constant x onshore wave power x function of height/depth

Similar to our present findings and also results of Halka and Sanford (2014) Todds Pt. work, but how to calculate α?

$$Eh\rho_{dry} = \alpha \int_{1985}^{2005} Pf(\frac{h}{d})\, dt$$