Wave-driven dynamics simulation of shoreline erosion from 1991 to 2014 in Chesapeake Bay

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Phase 6 shoreline erosion

- Digitally measured long-term shoreline erosion
- Partitioned in time based on hydrology
- Kilometer spatial resolution of CH3D grid

Phase 7 recommendation from Larry Sanford

Wave-driven time dependent dynamics simulation of shoreline erosion

$$Eh\rho_{dry} = \alpha'(P - P_{crit}) f(\frac{D}{h}) \quad (1)$$

$$P = \frac{1}{8}\rho g H_s^2 c_g \cos(\alpha) \quad (2)$$

Significance

- Coastline erosion is a challenge, particularly under climate change and sea level rise.
- A new piece of best available science.

VIMS shoreline erosion report 50 years ago

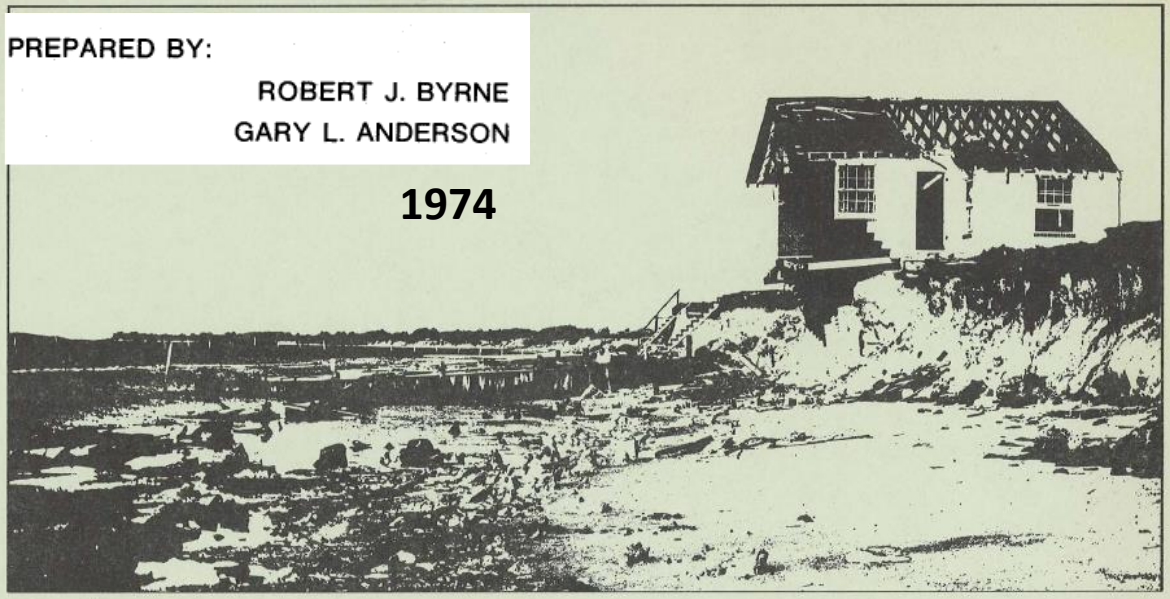
SHORELINE EROSION IN TIDEWATER VIRGINIA

PREPARED BY:

ROBERT J. BYRNE

GARY L. ANDERSON

1974



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The degree of shoreline recession which a particular site experiences is dependent upon many factors. The major factors are:

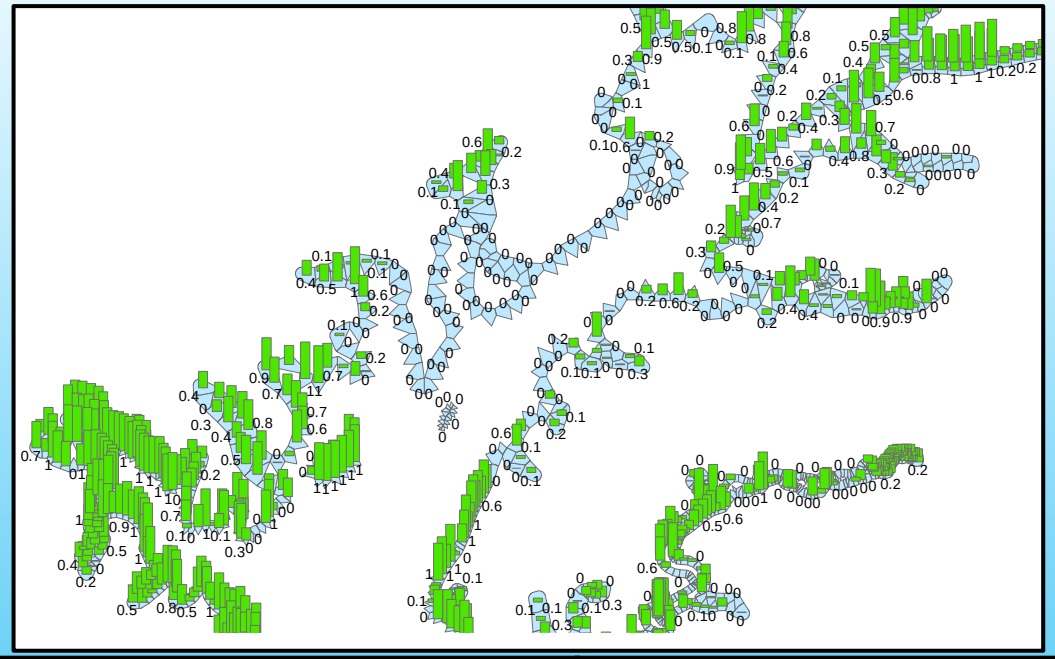
1. The intensity of wave action and the exposure to strong tidal currents.

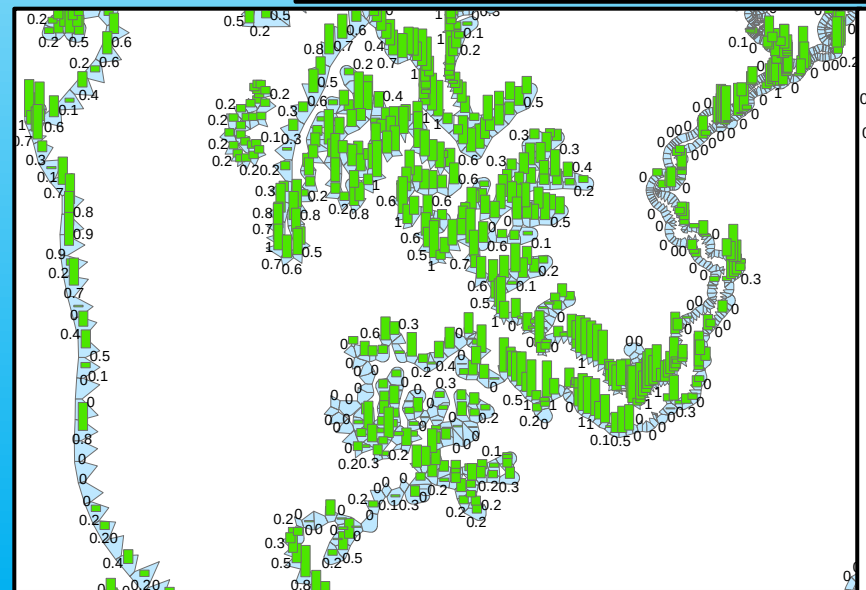
2. The character of the sediments at the site and the degree of protection offered by vegetative cover, specifically marsh grass, at the shoreline.

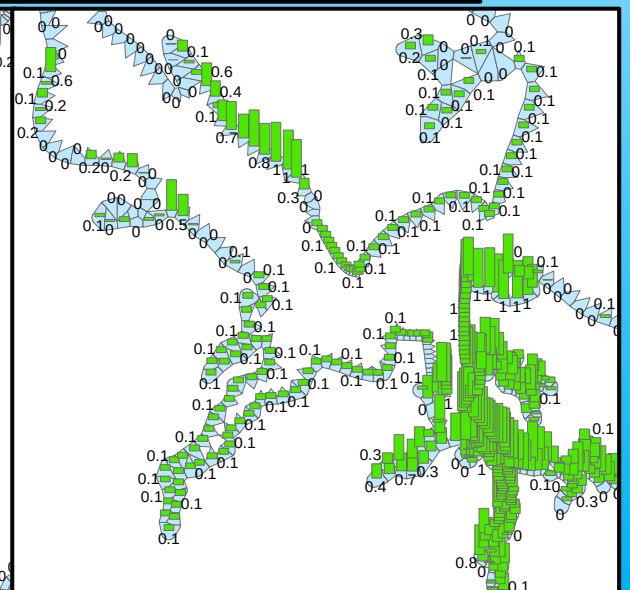
3. The supply of sand moving along the shoreline from other eroding areas or from streams along the shoreline.

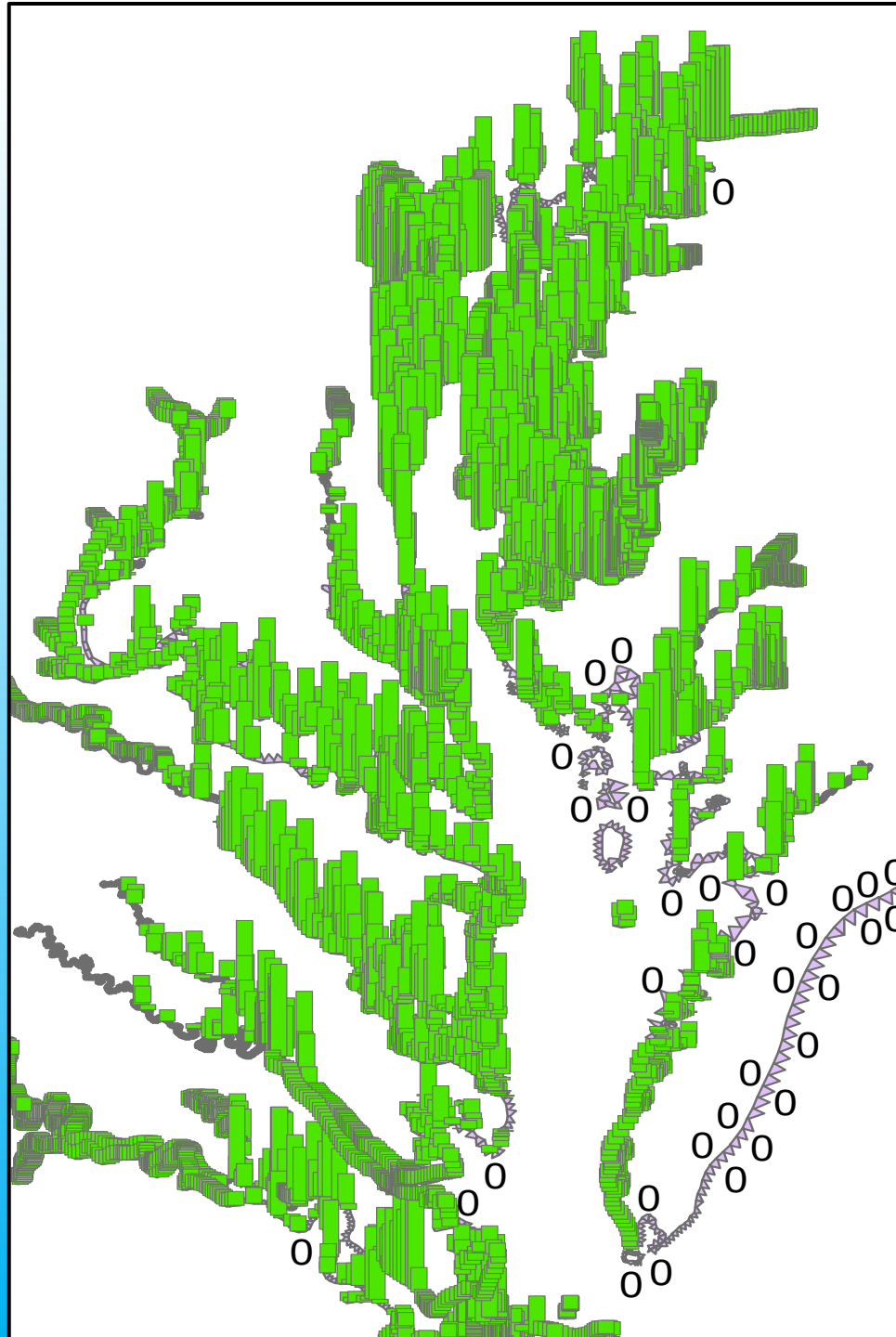
4. The gradient or slope of the fastland adjacent to the shoreline and the slope of the nearshore bottom.

Phase 6 shoreline protection

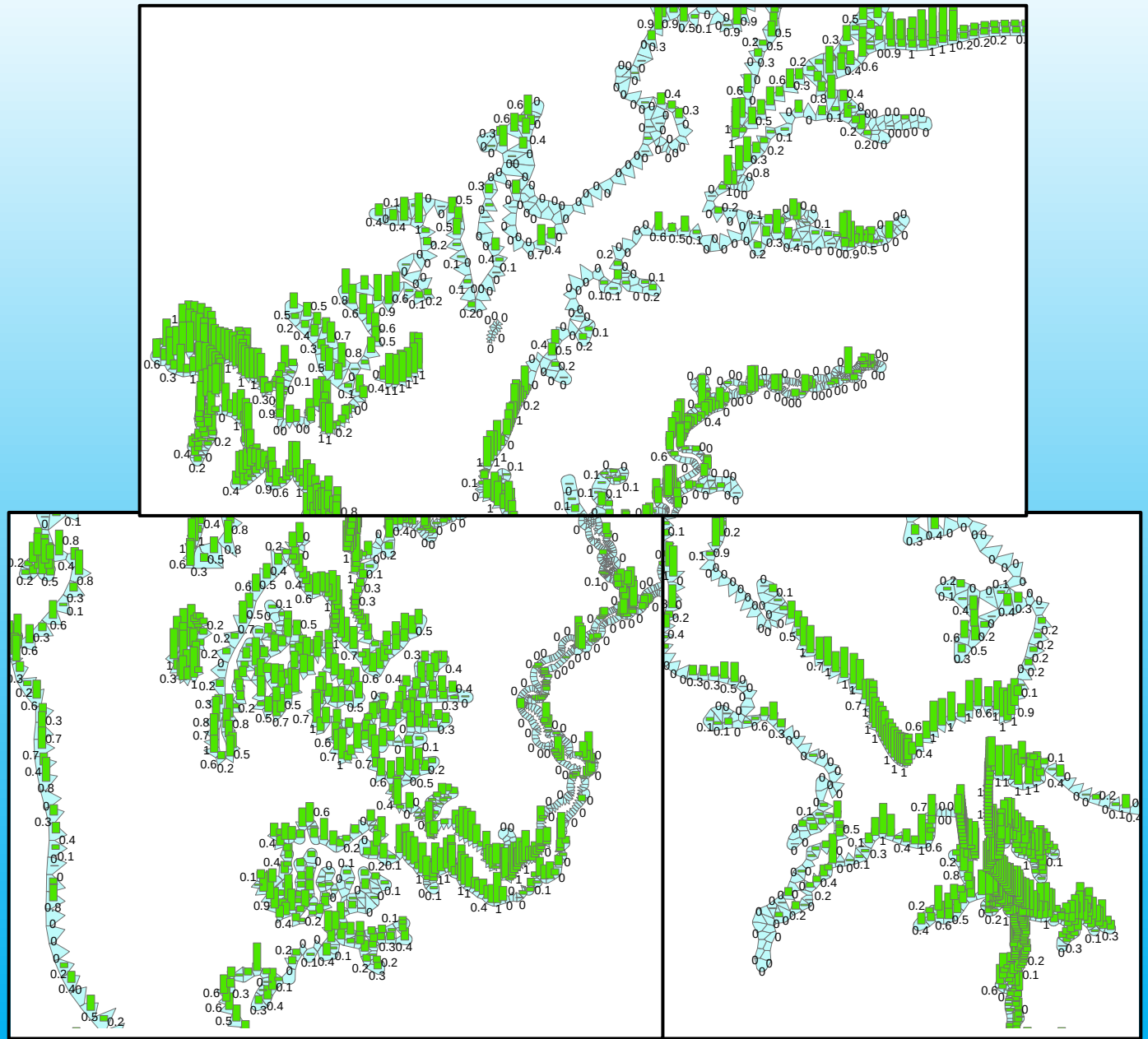


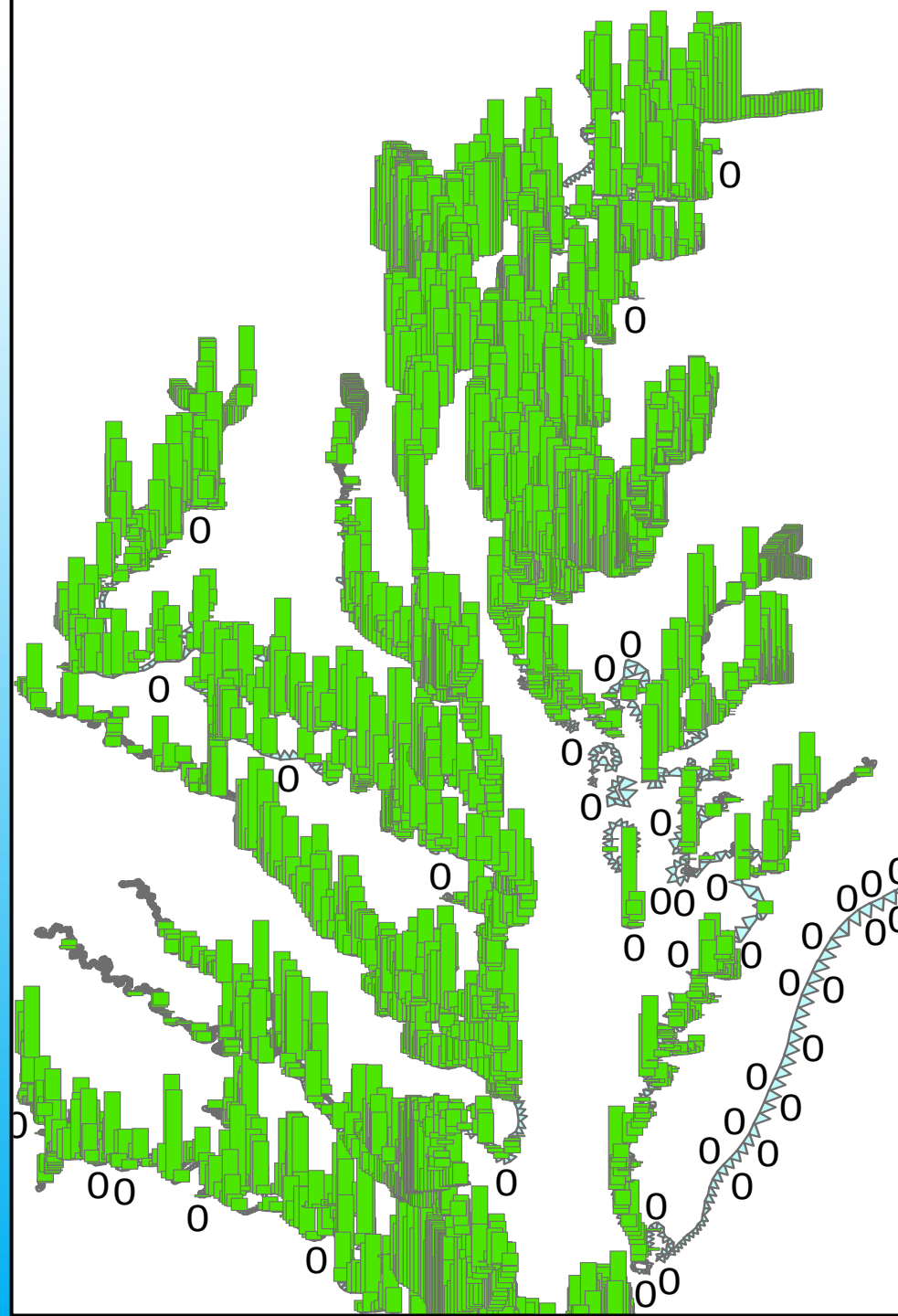




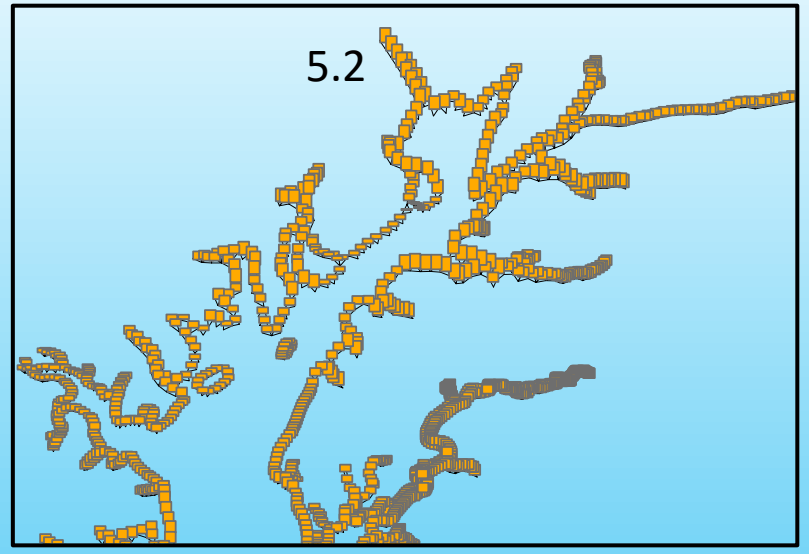


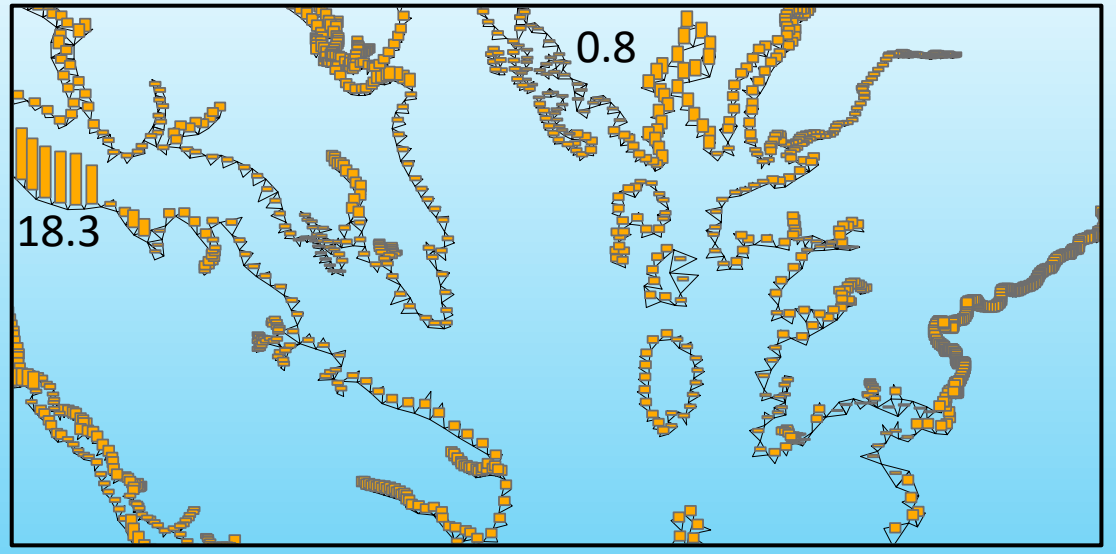
Phase 7 shoreline protection

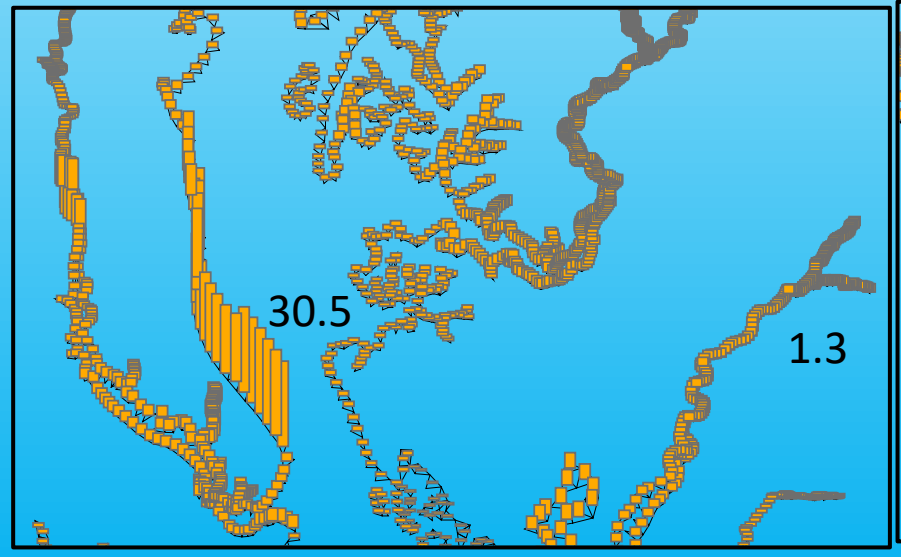




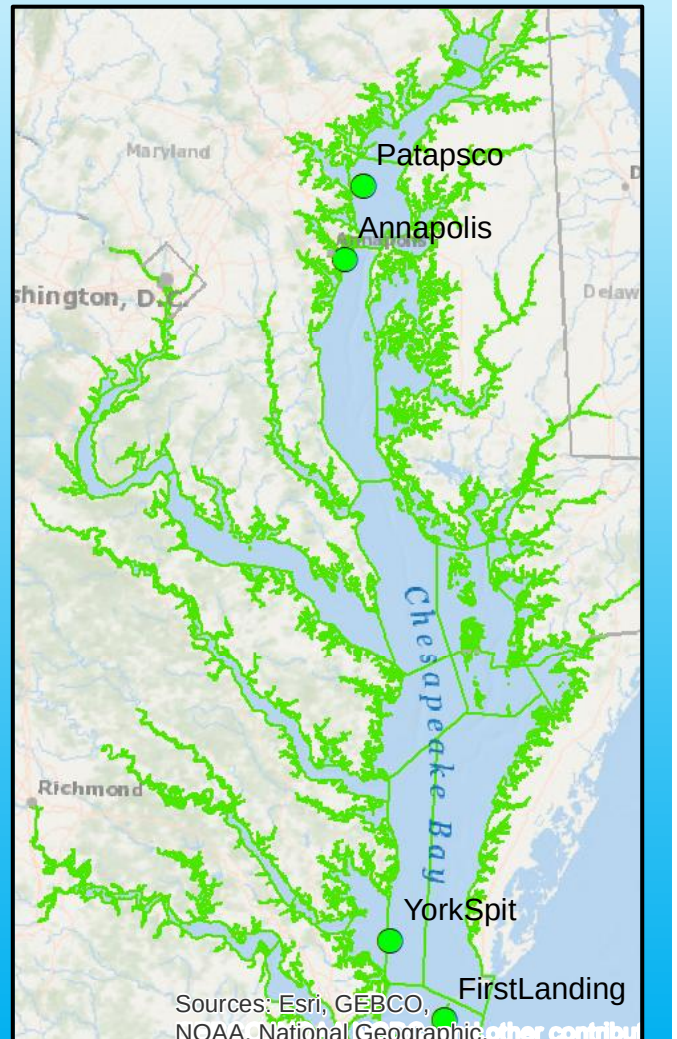
Bank height used for both Phases 6 and 7

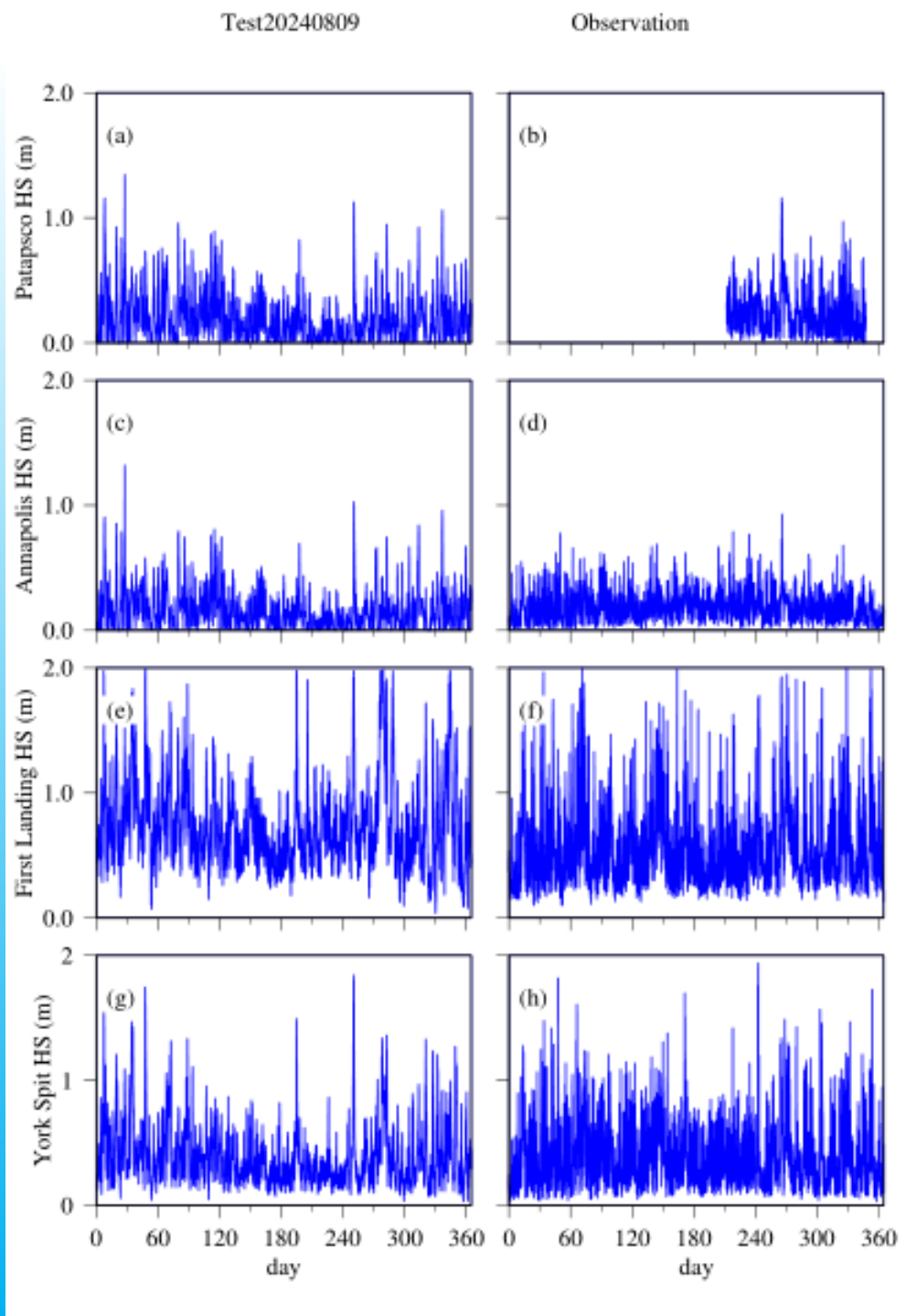






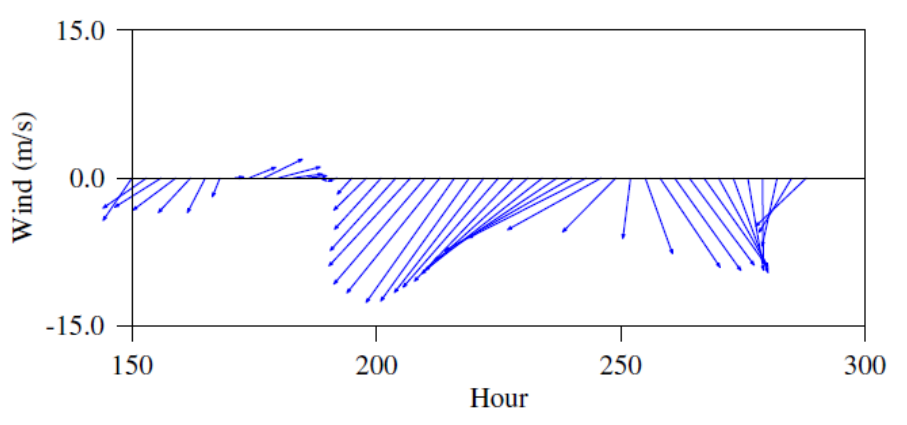
Comparison of simulated and observed wave height

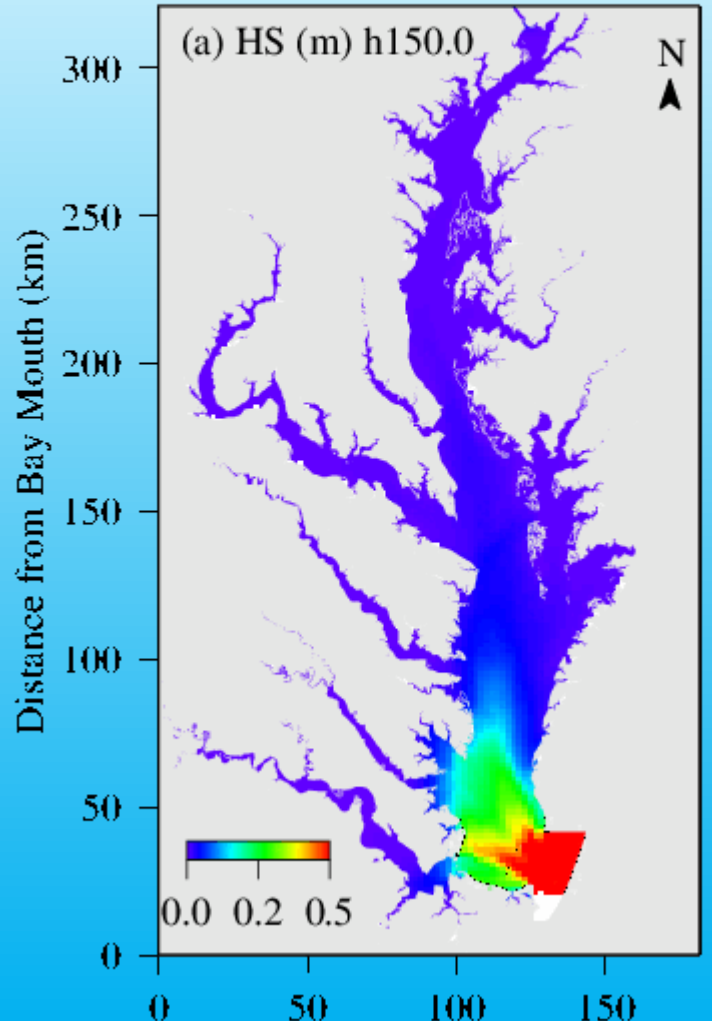




Significant wave height distribution and propagation

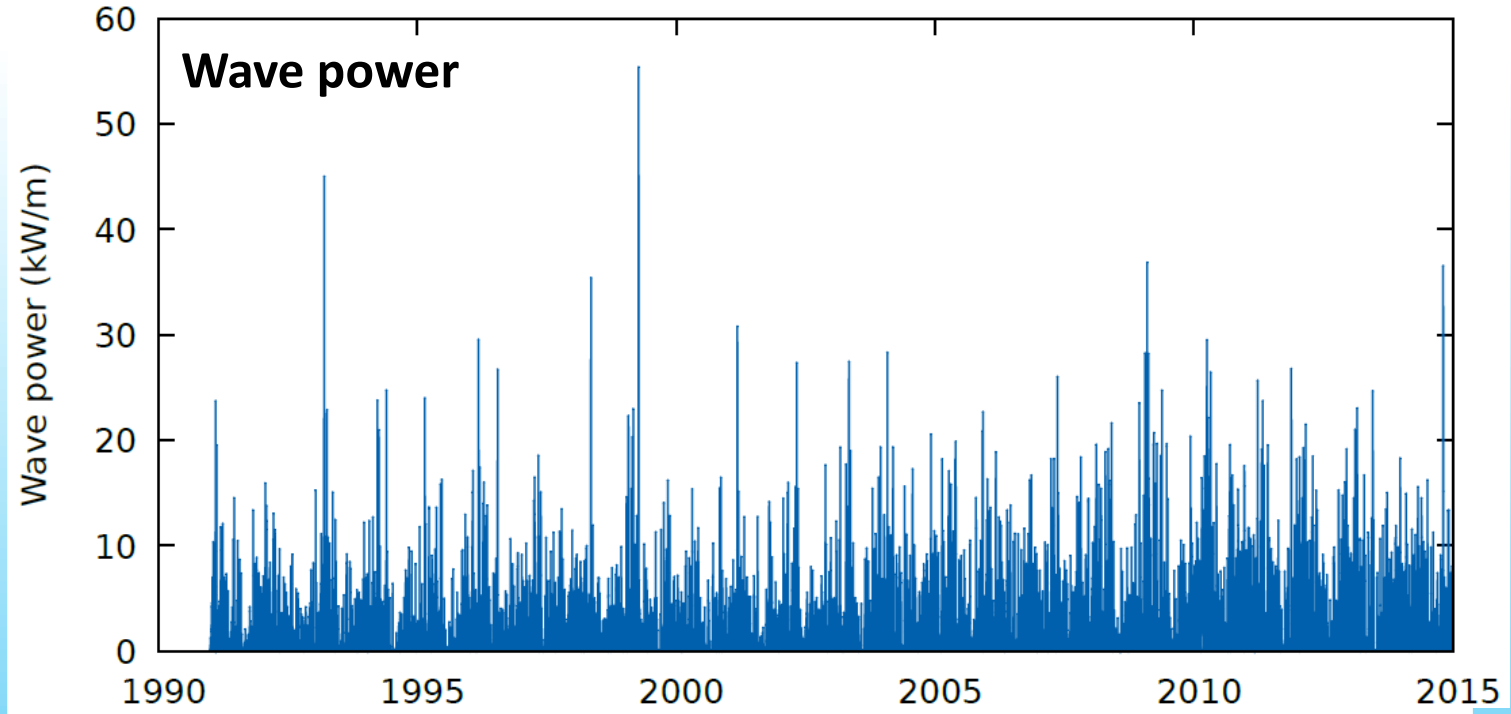
Wind Jan. 7-12, 1991

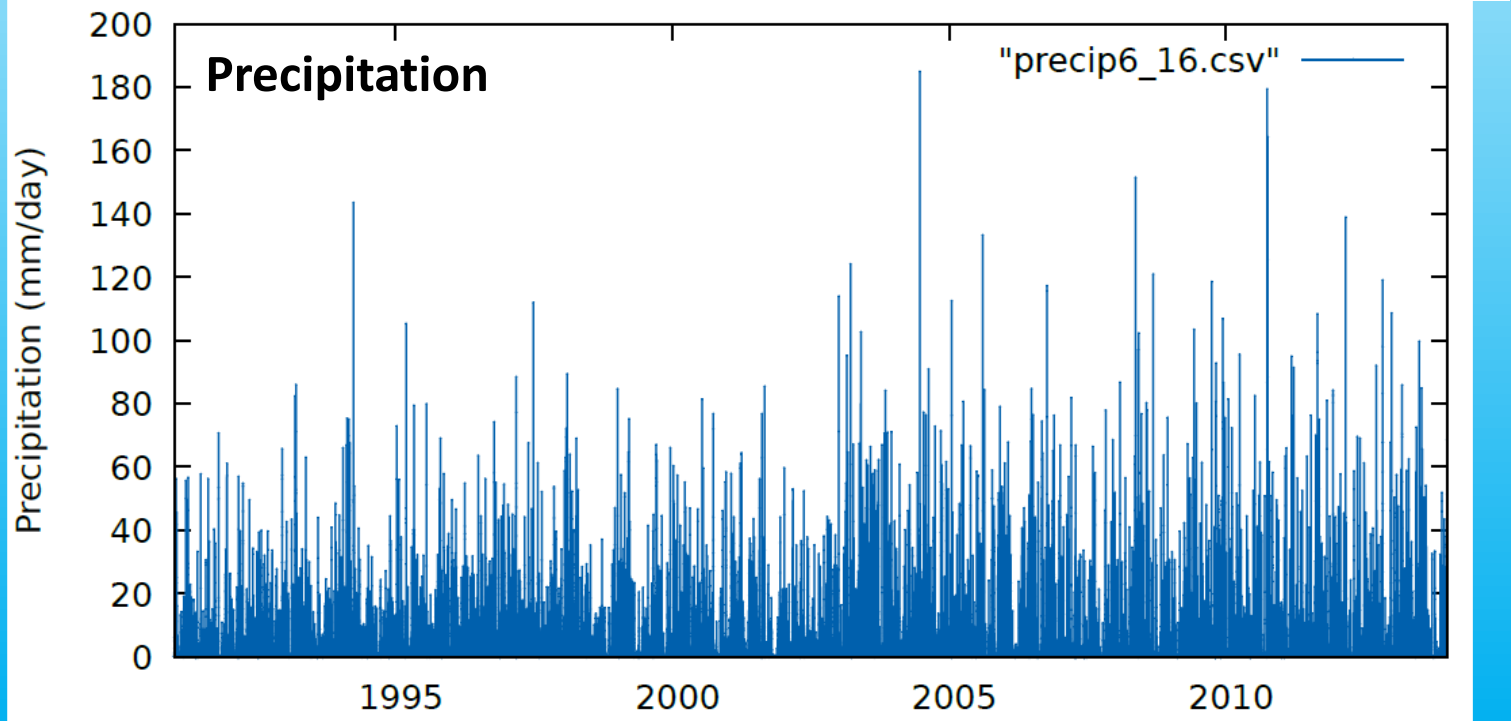




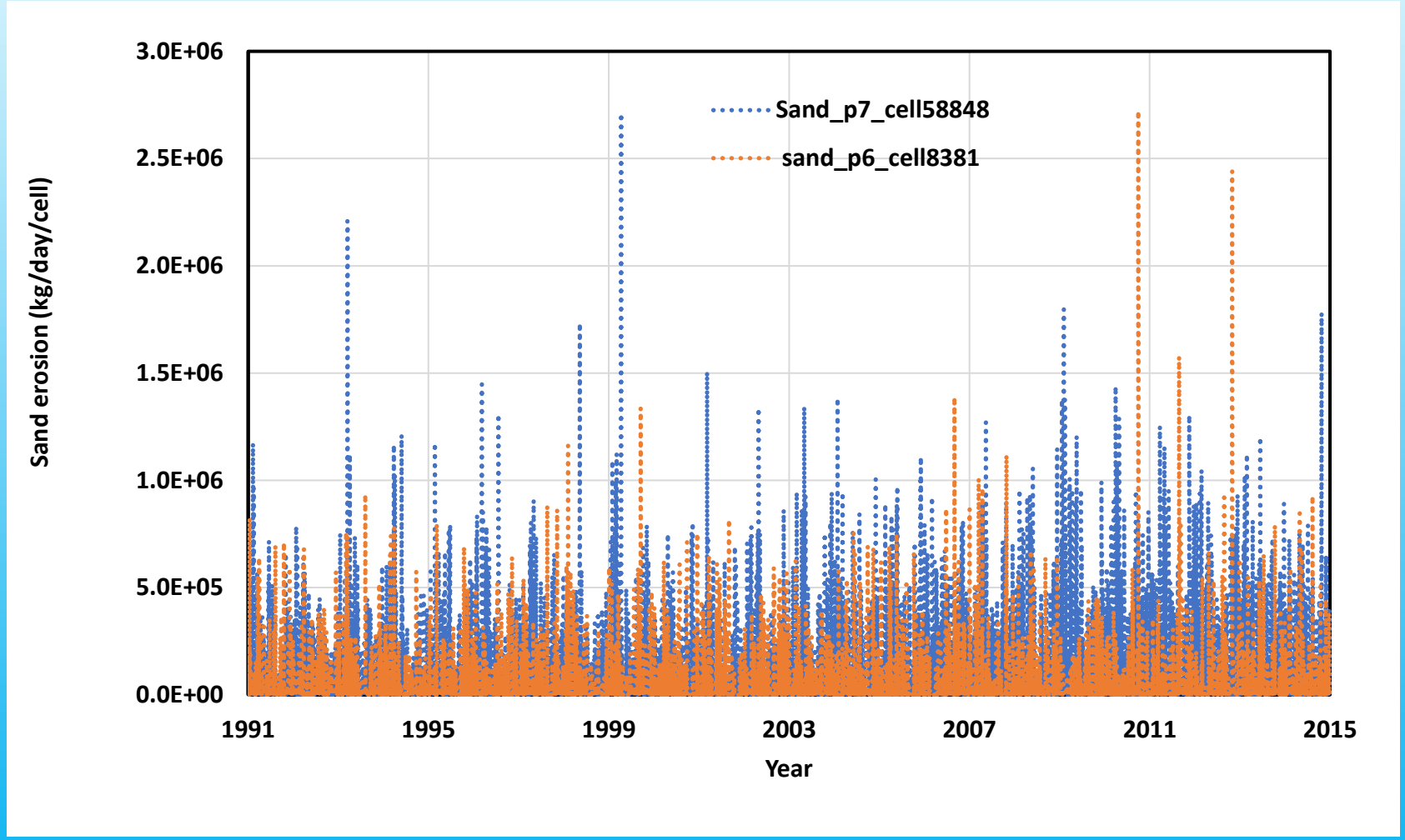
Wave power vs precipitation forcing at the Calvert Cliffs

Display similarity with high-frequency variability but differ in time.



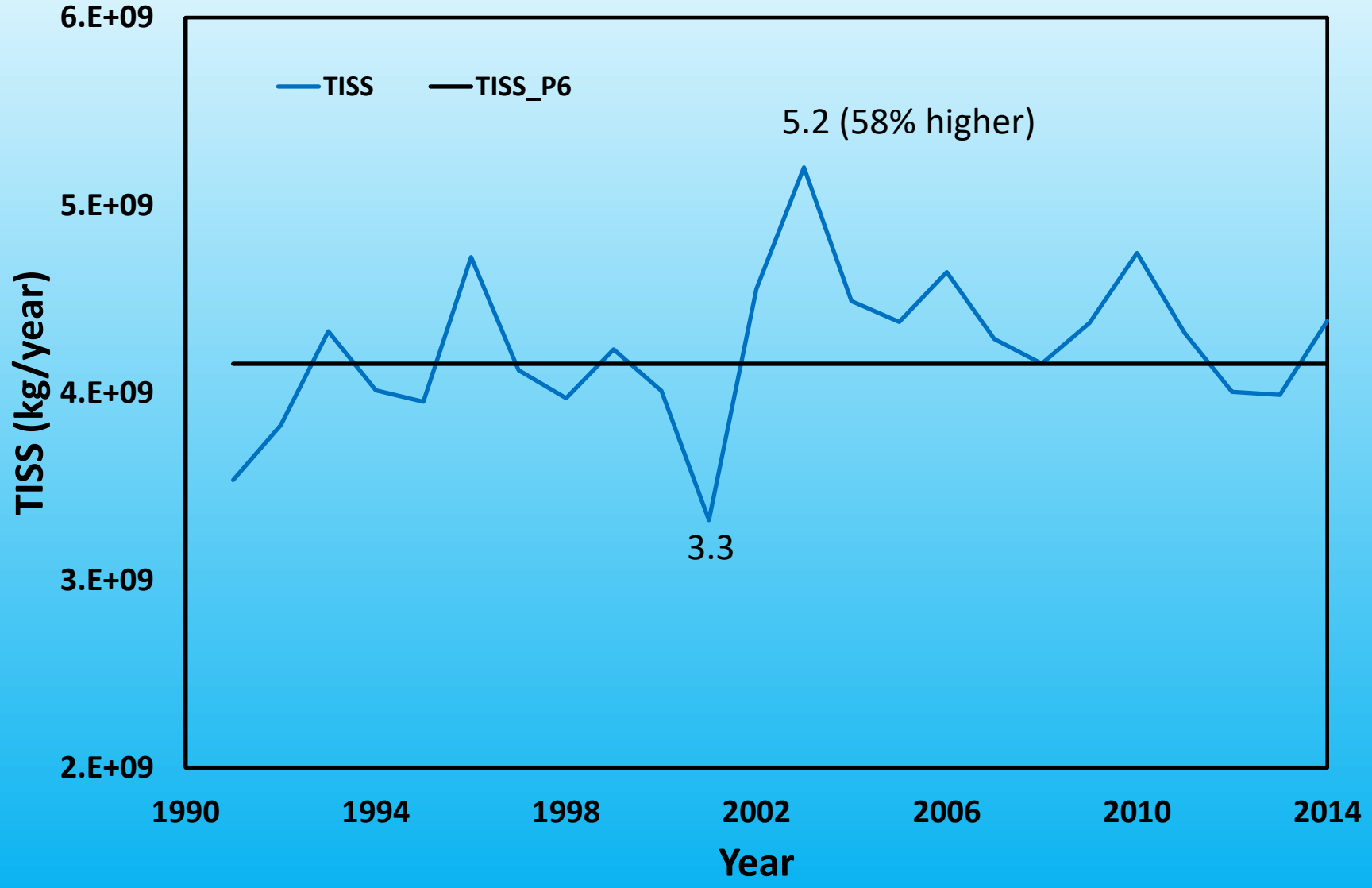


Precipitation-driven versus wave-driven shoreline erosion at the Calvert Cliffs

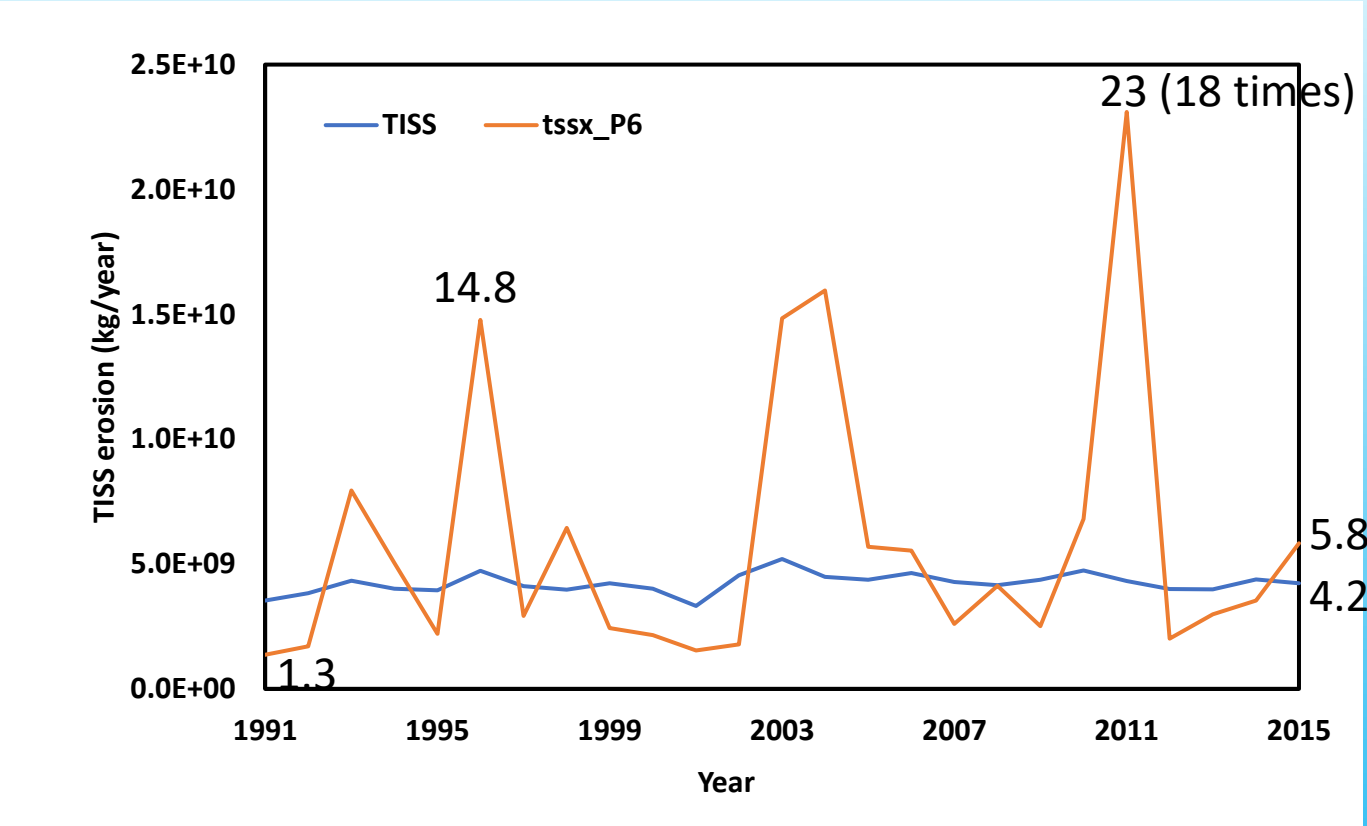


The overall erosion loads are the same but the timing differs.

Annual Total Inorganic Suspended Solids (TISS) shoreline erosion – 58% of interannual variability

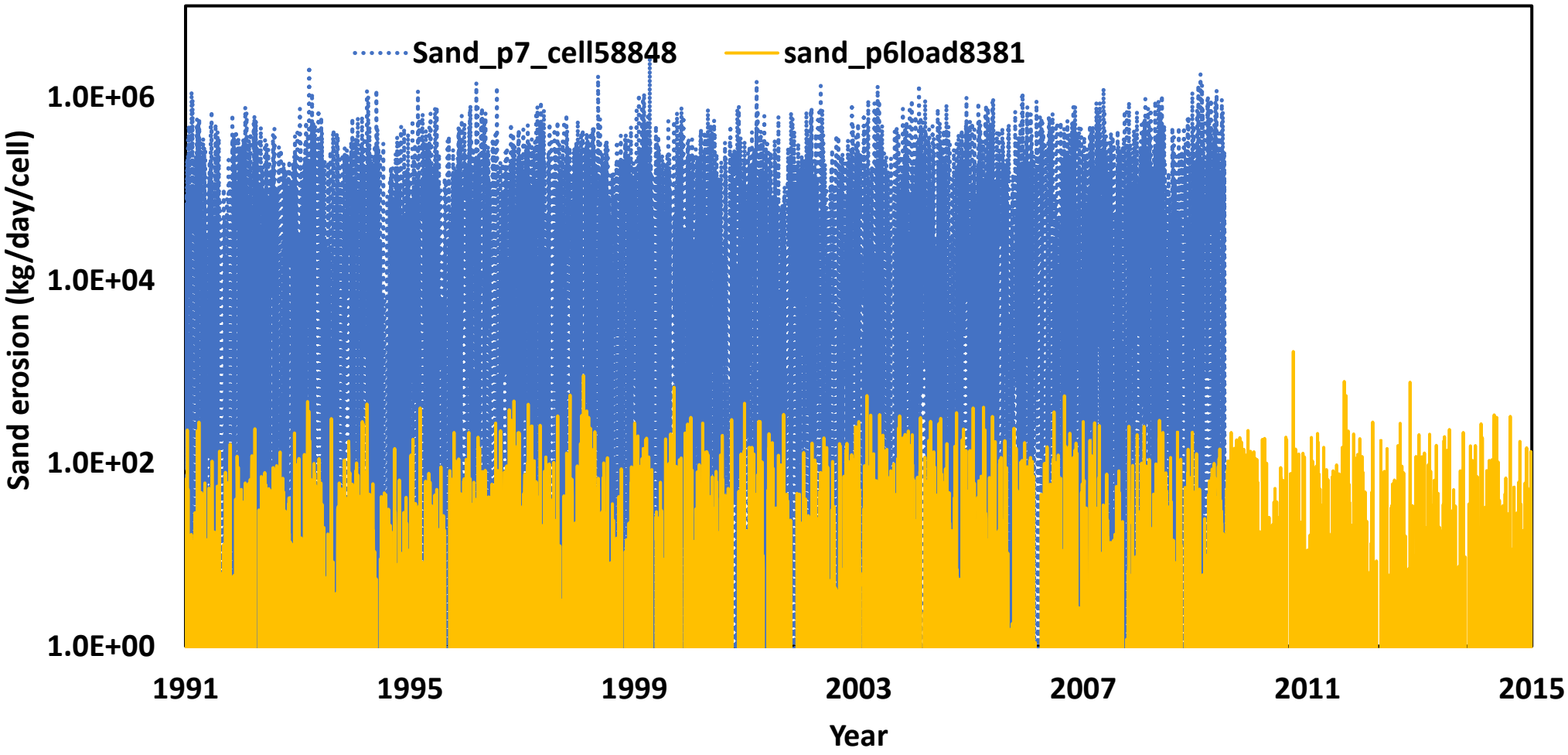


Wave-driven annual shoreline erosion of TISS versus P6 watershed loads

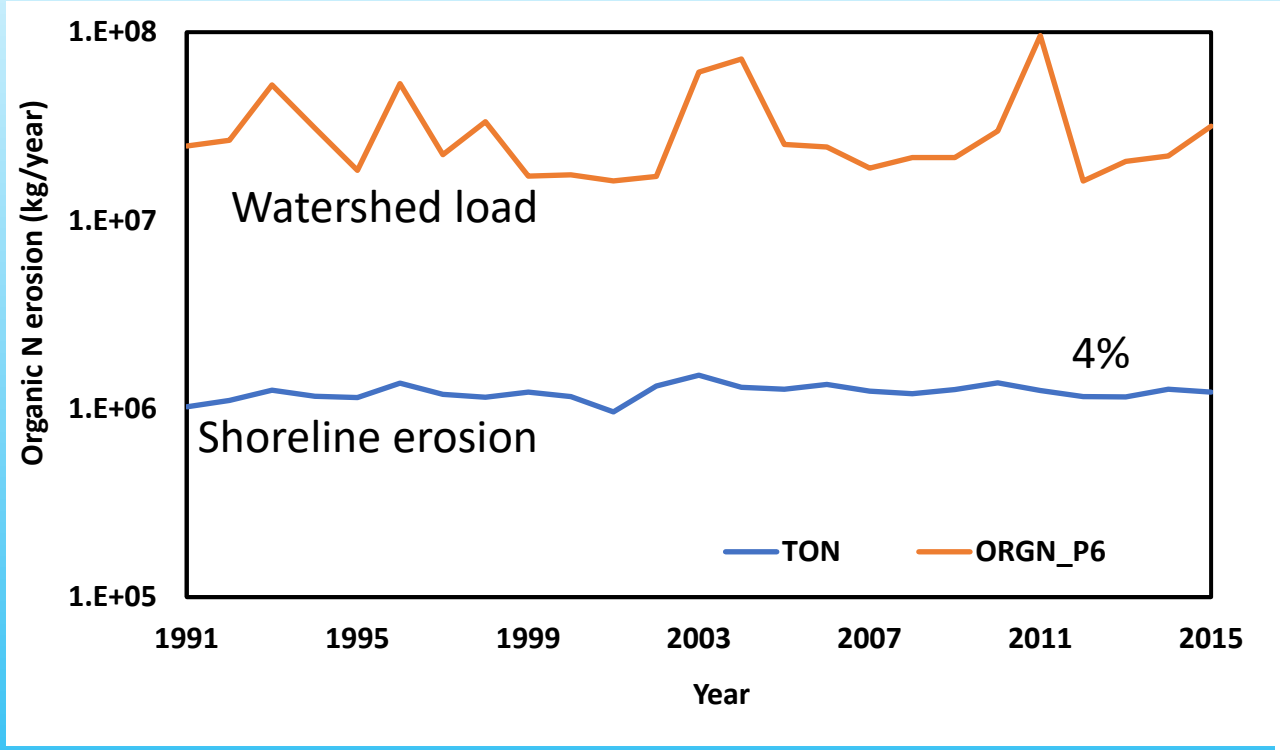


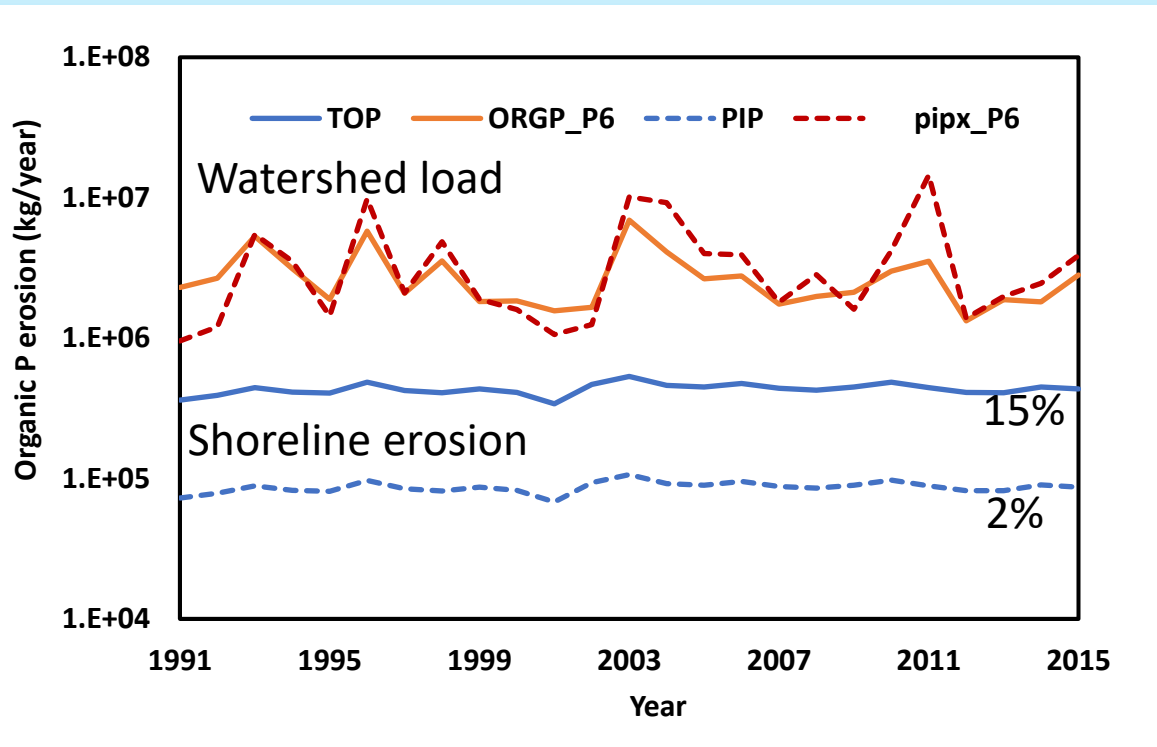
Run 20250317
2015 is the average

Local shoreline erosion (blue) versus watershed load (orange) at the Calvert Cliff (2684 times higher)



Wave-driven organic nitrogen and phosphorus shoreline erosion versus watershed loads

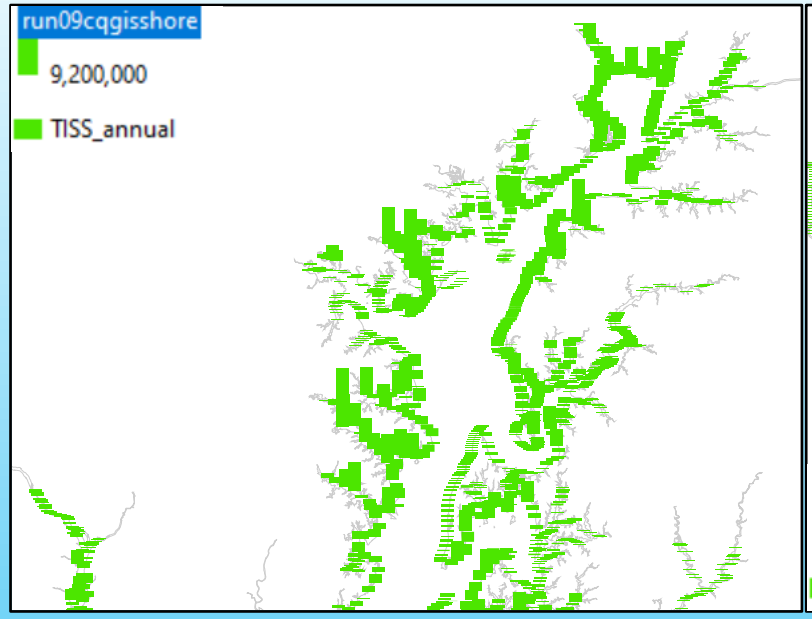


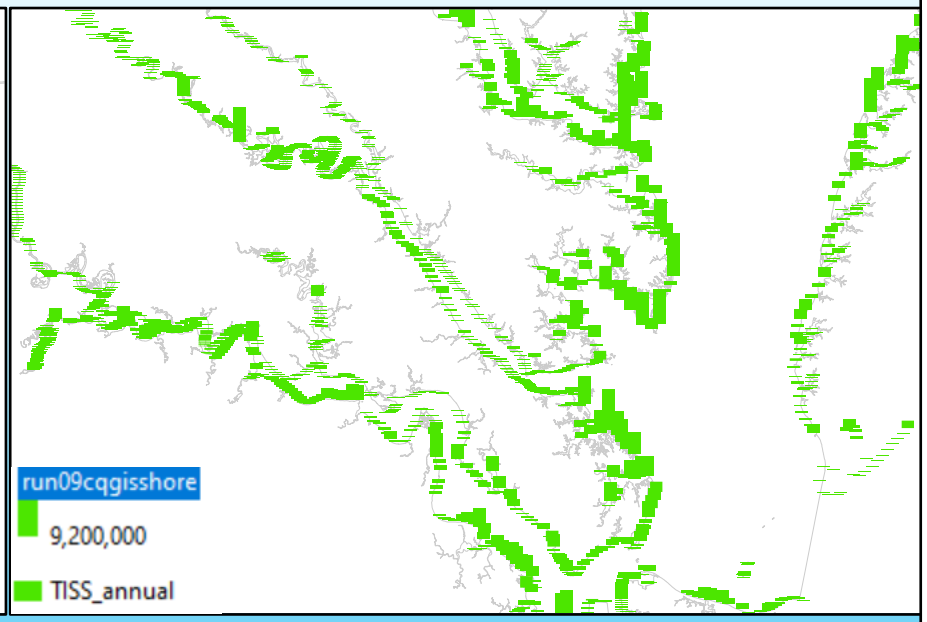


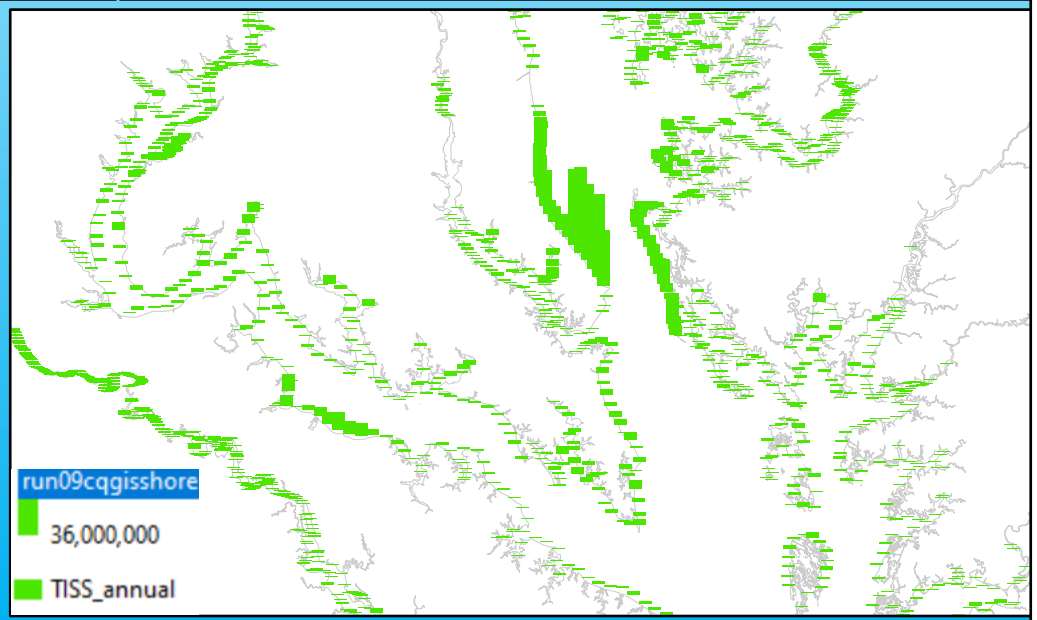
Local shoreline erosion versus watershed load in Fishing Bay

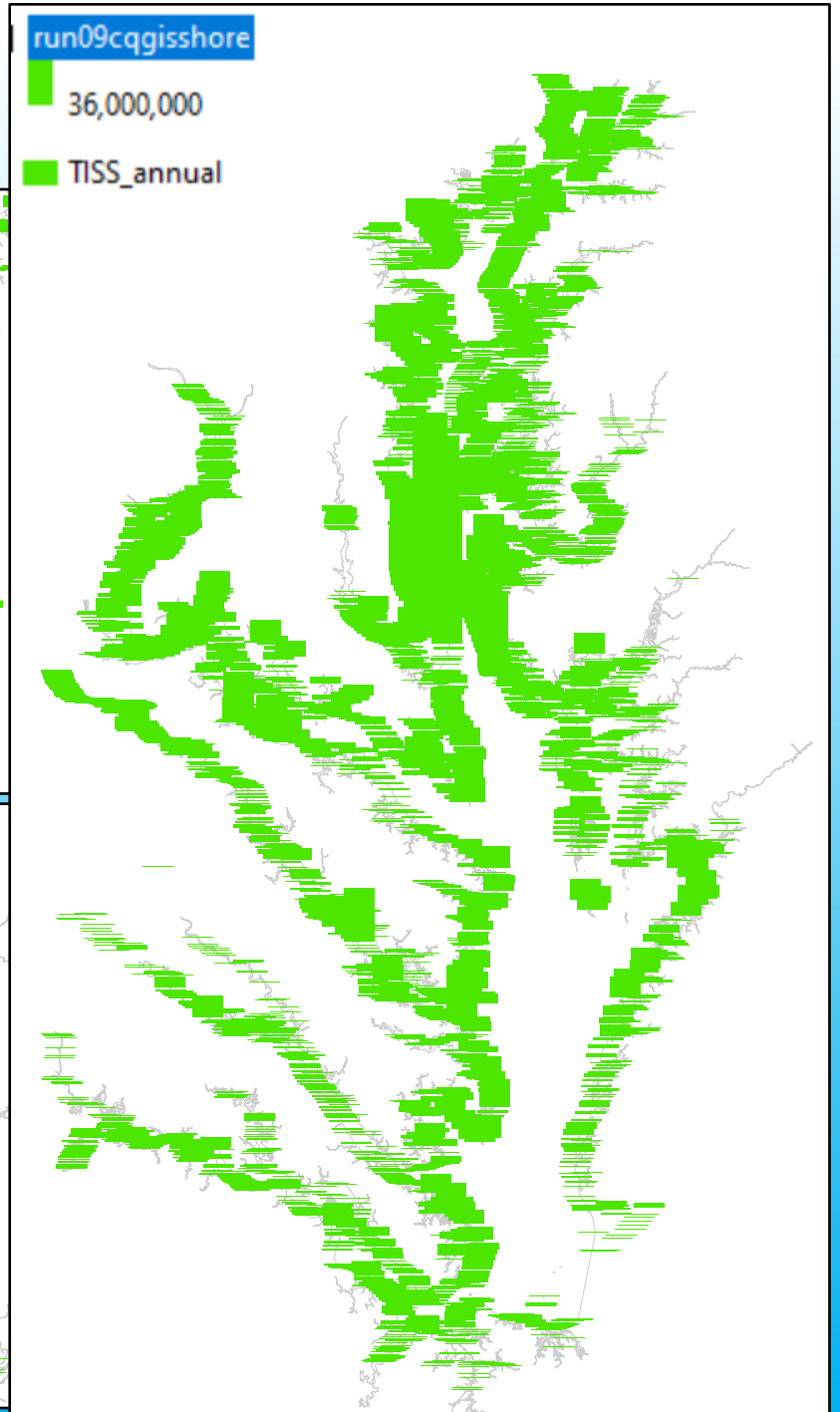
	TSS	Organic N	Organic P	PIP
Watershed load (kg/year)	7.84746e+07	1.7708e+06	250318	173450
Shoreline erosion (kg/year)	7.71105e+08	223620	135945	22131
Ratio between shoreline erosion and watershed Load	10	0.13	0.54	0.13

Spatial distribution of shoreline erosion









Run 20250317

Data deliverable in NETCDF

- No nitrate, ammonium and phosphate.
- No labile organic matter.

```
dimensions:
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        time = 8764 ;
variables:
        int cellid(cell) ;
                cellid:Cell = "ID" ;
        int time(time) ;
                time:Days = "since 01011991" ;
        float sand(cell, time) ;
                sand:Erosion = "kg/d/cell" ;
        float silt(cell, time) ;
                silt:Erosion = "kg/d/cell" ;
        float clay(cell, time) ;
                clay:Erosion = "kg/d/cell" ;
        float orgs(cell, time) ;
                orgs:Erosion = "kg/d/cell" ;
        float RPOC(cell, time) ;
                RPOC:Erosion = "kg/d/cell" ;
        float G3OC(cell, time) ;
                G3OC:Erosion = "kg/d/cell" ;
        float RPON(cell, time) ;
                RPON:Erosion = "kg/d/cell" ;
        float G3ON(cell, time) ;
                G3ON:Erosion = "kg/d/cell" ;
        float RPOP(cell, time) ;
                RPOP:Erosion = "kg/d/cell" ;
        float G3OP(cell, time) ;
                G3OP:Erosion = "kg/d/cell" ;
        float PIP(cell, time) ;
                PIP:Erosion = "kg/d/cell" ;
}
```

Message

- The wave model functioned properly in the whole Bay.
- Wave power redistributed shoreline erosion in space and time but total P6 and P7 shoreline erosion is the same.
- Total sediment erosion is equivalent to total sediment load from the watershed Bay-wide but can be higher by up to three orders of magnitude on a local scale.
- Nitrogen and phosphorus from shoreline erosion account for 4 and 15% of watershed load for the whole Bay but could increase three-fold in some embayments.

Wind over 24 years
Blue is u and red is v