CCRFR

COMMONWEALTH CENTER FOR RECURRENT FLOODING RESILIENCY

Sea Level Rise & Adaptation in Virginia

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Emily Steinhilber, ODU

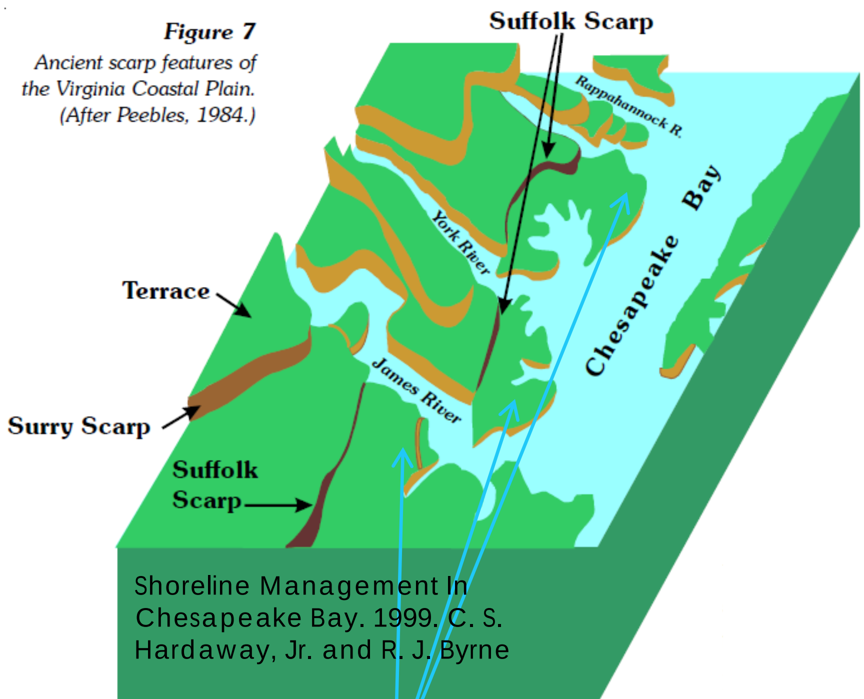
August 31, 2016

EO 57 Work Group Meeting

Outline

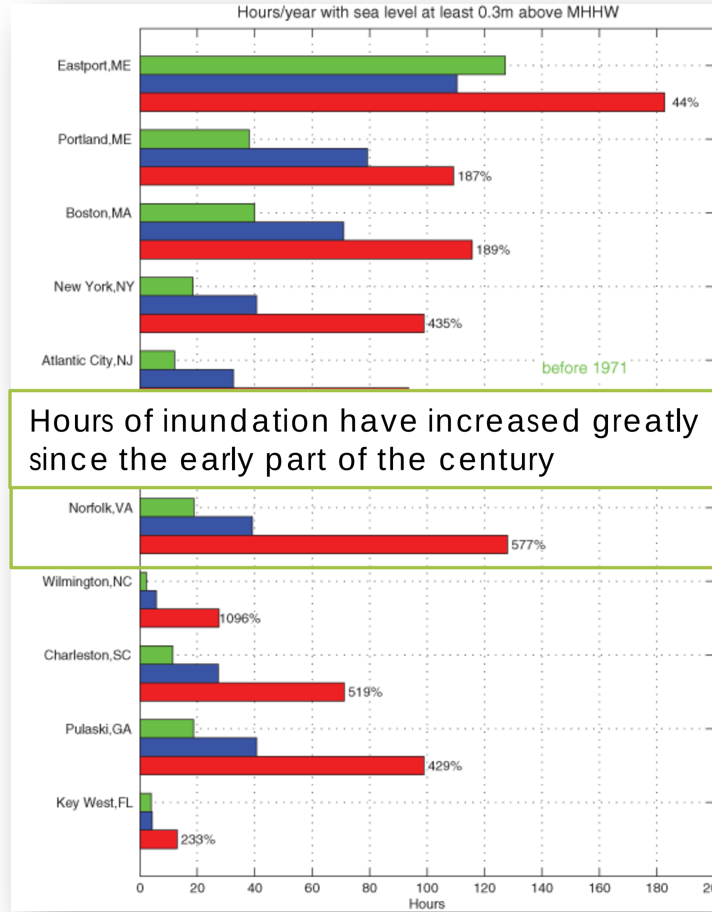
1. Drivers of SLR and current projections
2. Impacts of SLR to natural and built environment
3. Current Adaptation efforts
4. How is new Center poised to help with these issues?

Sea level rise is a particular problem for Virginia



Shoreline Management In Chesapeake Bay. 1999. C. S. Hardaway, Jr. and R. J. Byrne

Here are extensive marshes & flat, easily flooded lands



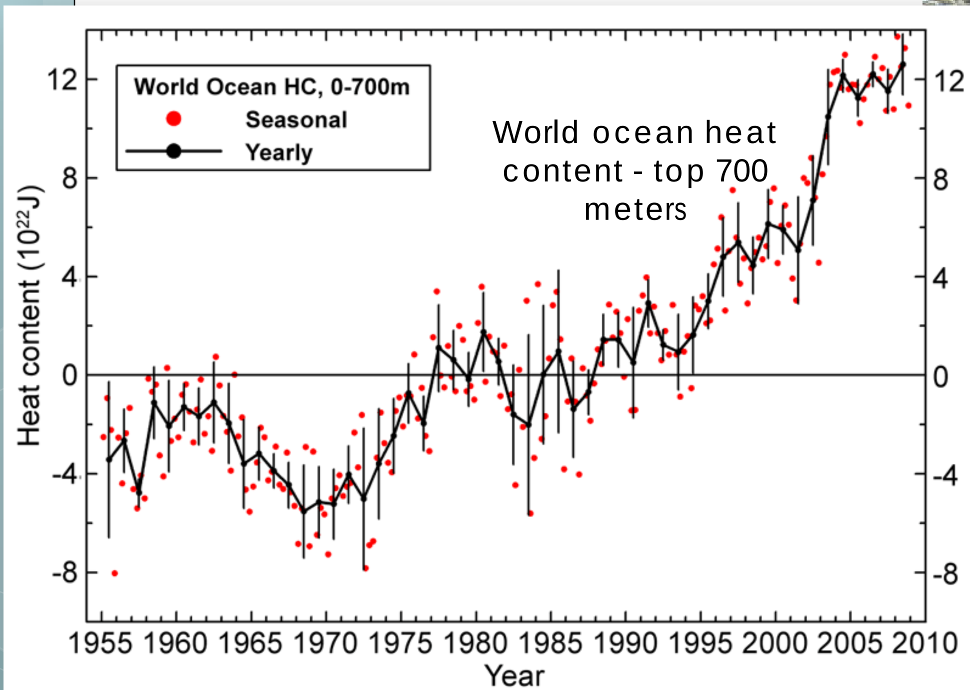
Hours of inundation have increased greatly since the early part of the century

Ezer, T., & Atkinson, L. P. (2014). Accelerated flooding along the US East Coast: on the impact of sea-level rise, tides, storms, the Gulf Stream, and the North Atlantic oscillations. *Earth's Future*, *2*(8), 362-382.

Global Processes:

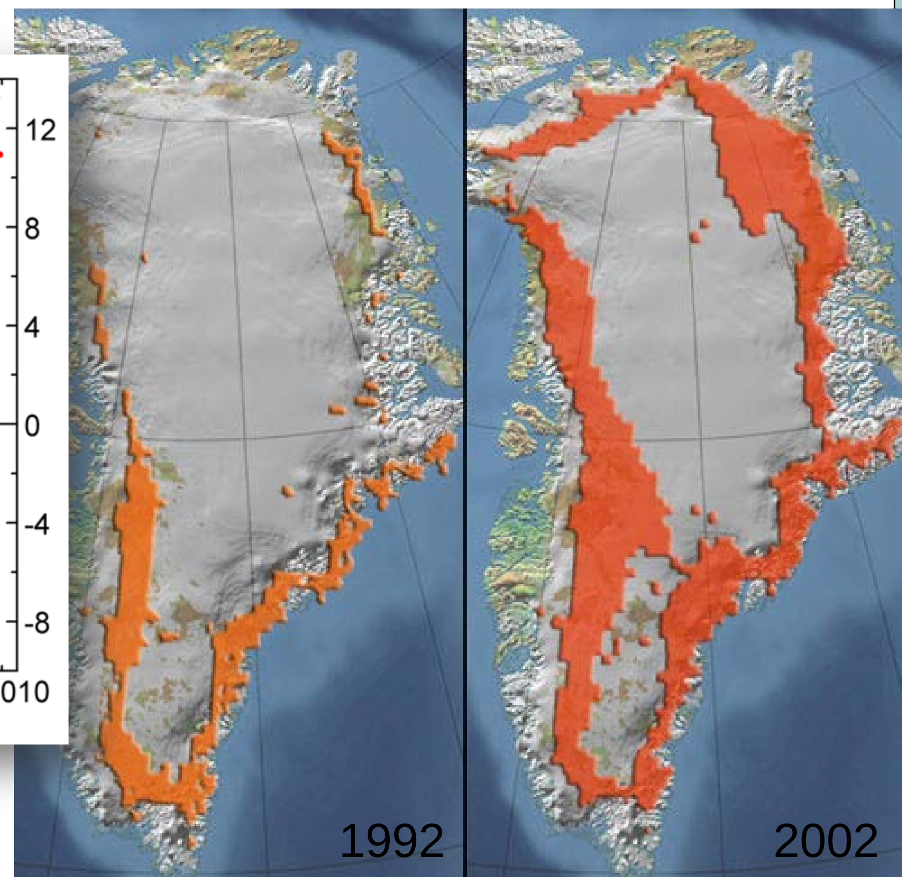
Eustatic: Global SL changes relative to a fixed point (like the center of the earth) having to do with changes in ocean volume

Steric: Global SL changes from thermal expansion of water and differences in salinity



http://www.ncdc.noaa.gov/indicators/

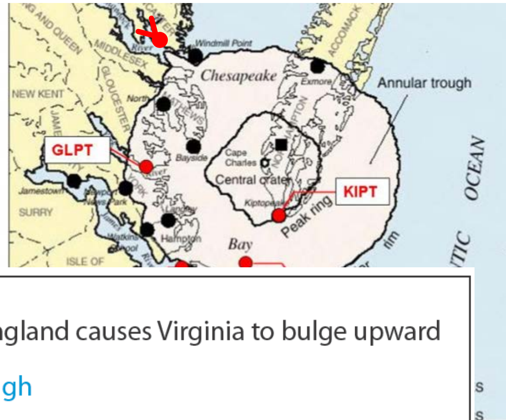
Seasonal ice melting in Greenland

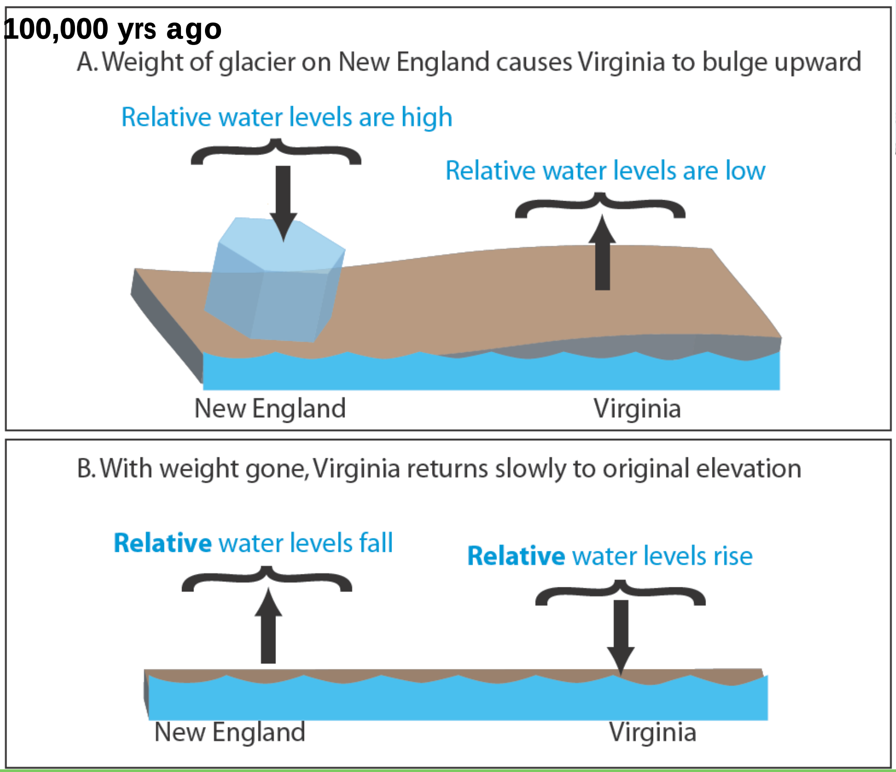


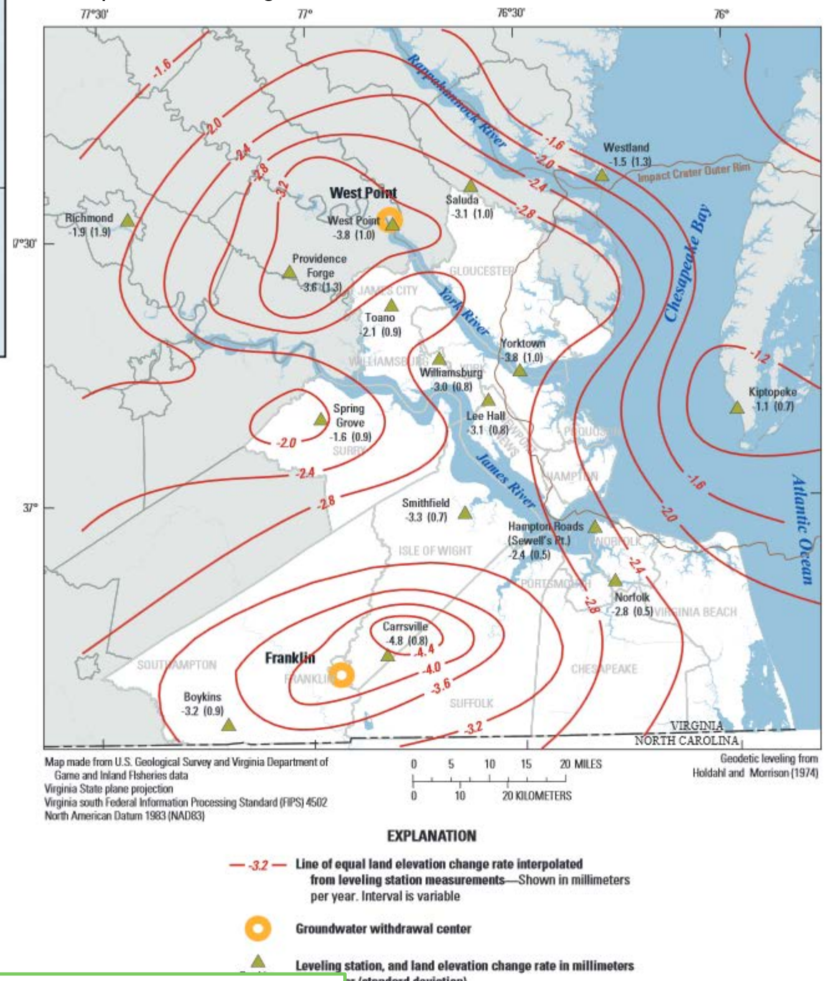
Regional Processes:

Subsidence

Eggleston, Jack, and Pope, Jason, 2013, Land subsidence and relative sea-level rise in the southern Chesapeake Bay region: U.S. Geological Survey Circular 1392, 30 p., http://dx.doi.org/10.3133/cir1392.



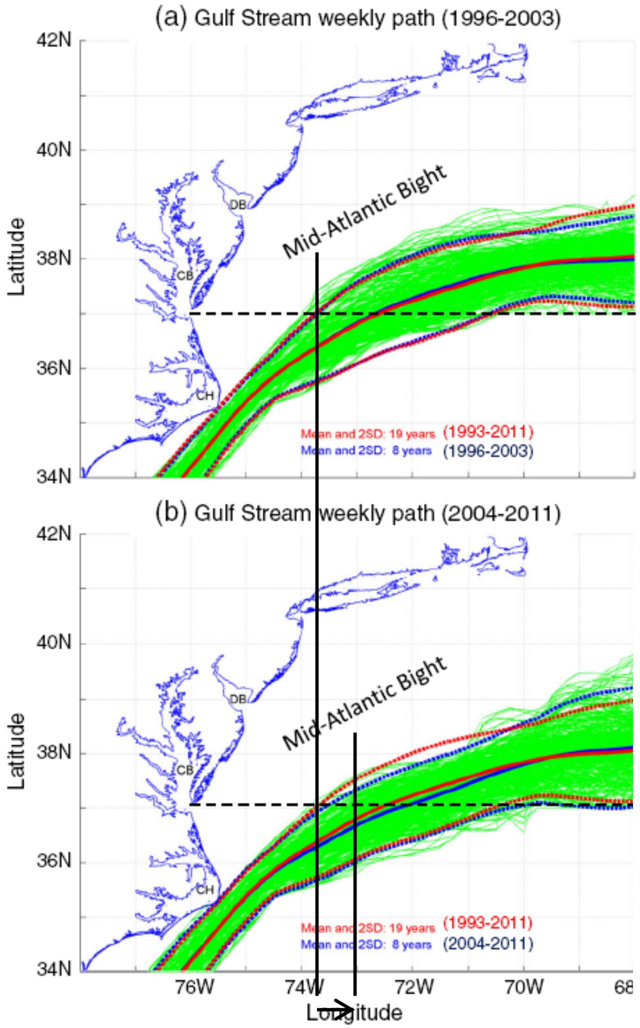




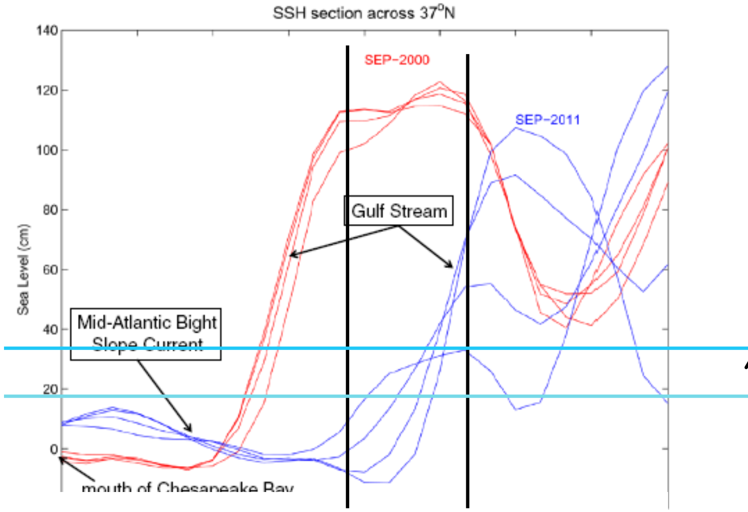
Chesapeake Bay Land Subsidence and Sea Level Change: An Evaluation of Past and Present Trends and Future Outlook. Boon, Brubaker, Forrest. 2010. Virginia Institute of Marine Science. Special Report No. 425 in Applied Marine. Science and Ocean Engineering

Local Processes:

Shift in Gulf Stream

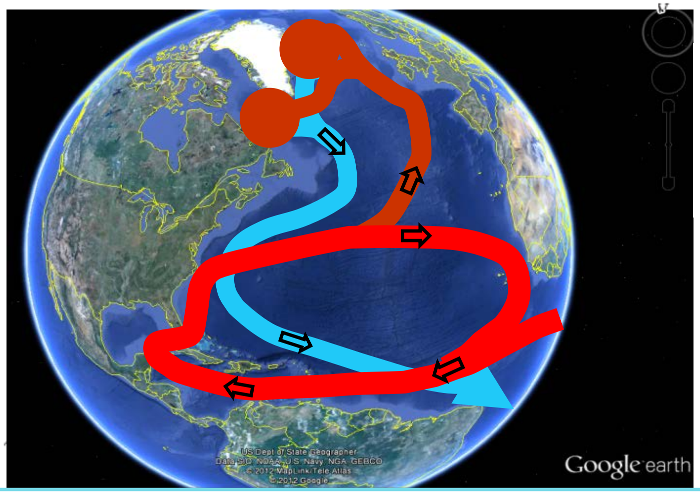


Shift in location



Change in water level

Shift in location



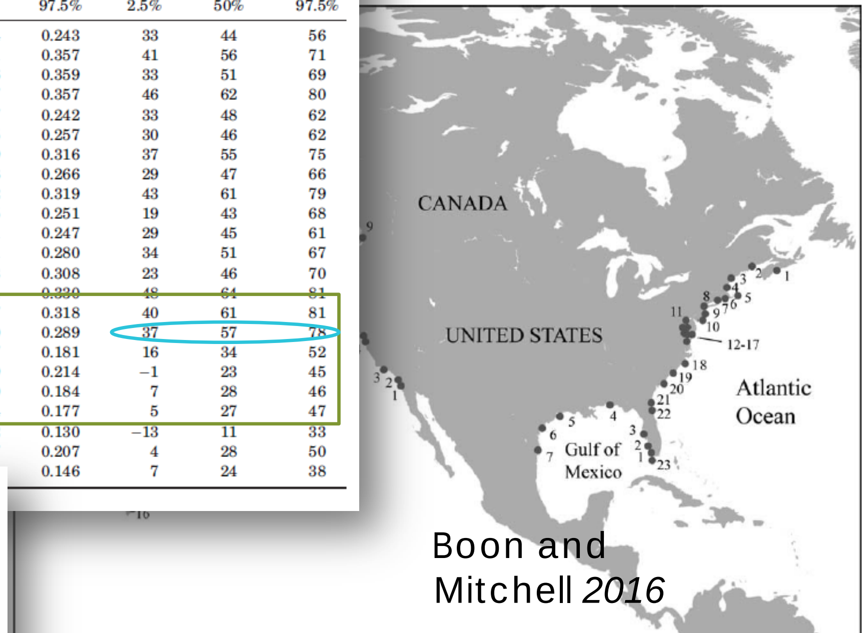
Atlantic Meridional Overturning Circulation

Ezer, T., L. P. Atkinson, W. B. Corlett and J. L. Blanco (2013), Gulf Stream's induced sea level rise and variability along the U.S. mid-Atlantic coast, J. Geophys. Res. Oceans, 118, 685–697

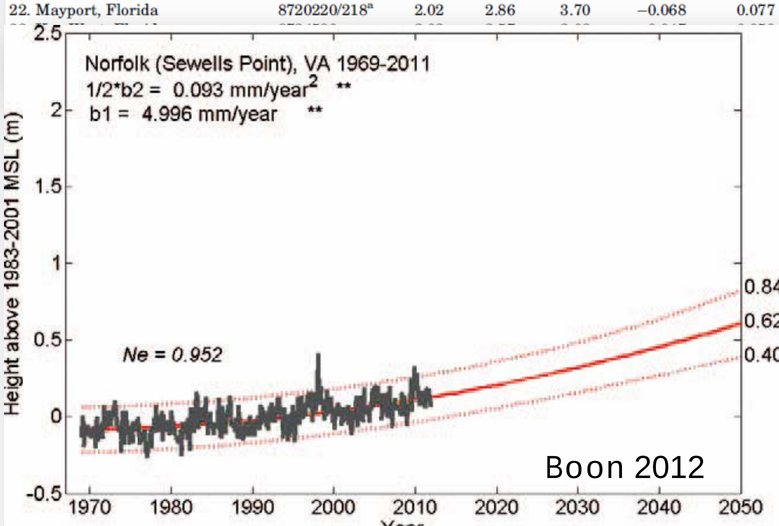
Projecting Sea Level Rise for Virginia

Table 1. *East Coast rise (β_1*), acceleration (β_2*), and projected year 2050 height percentiles given 1969–2014 monthly RMSL.*

Station	ID Number	β_1* (mm/y) 2.5%	β_1* (mm/y) 50%	β_1* (mm/y) 97.5%	β_2* (mm/y^2) 2.5%	β_2* (mm/y^2) 50%	β_2* (mm/y^2) 97.5%	2050 Projection (cm) 2.5%	2050 Projection (cm) 50%	2050 Projection (cm) 97.5%
1. Halifax, Nova Scotia	00490/491[a]	1.99	2.62	3.29	0.112	0.174	0.243	33	44	56
2. Eastport, Maine	8410140	0.73	1.73	2.72	0.183	0.271	0.357	41	56	71
3. Portland, Maine	8418150	0.15	1.23	2.41	0.153	0.256	0.359	33	51	69
4. Boston, Massachusetts	8443970	2.08	3.07	4.08	0.164	0.257	0.357	46	62	80
5. Nantucket, Massachusetts	8449130	2.97	3.64	4.37	0.071	0.157	0.242	33	48	62
6. Newport, Rhode Island	8452660	2.29	3.04	3.82	0.074	0.165	0.257	30	46	62
7. New London, Connecticut	8461490	2.59	3.52	4.45	0.098	0.209	0.316	37	55	75
8. The Battery, New York	8518750	2.63	3.49	4.37	0.047	0.158	0.266	29	47	66
9. Sandy Hook, New Jersey	8531680	3.25	4.26	5.23	0.104	0.212	0.319	43	61	79
10. Atlantic City, New Jersey	8534720	3.71	4.56	5.48	−0.055	0.105	0.251	19	43	68
11. Baltimore, Maryland	8574680	2.57	3.38	4.18	0.049	0.151	0.247	29	45	61
12. Annapolis, Maryland	8575512	2.66	3.53	4.41	0.080	0.181	0.280	34	51	67
13. Washington, DC	8594900	2.15	3.24	4.27	0.011	0.163	0.308	23	46	70
14. Solomons Island, Maryland	8577330	3.71	4.76	5.70	0.113	0.221	0.330	48	64	81
15. Yorktown, Virginia	8637624/689[a]	3.75	4.82	5.86	0.059	0.197	0.318	40	61	81
16. Norfolk, Virginia	8638610	4.15	5.11	6.04	0.034	0.160	0.289	37	57	78
17. Kiptopeke, Virginia	8632200	2.96	3.68	4.46	−0.037	0.077	0.181	16	34	52
18. Wilmington, North Carolina	8658120	0.84	1.70	2.58	−0.054	0.079	0.214	−1	23	45
19. Charleston, South Carolina	8665530	2.09	2.79	3.49	−0.048	0.070	0.184	7	28	46
20. Fort Pulaski, Georgia	8670870	2.44	3.21	3.96	−0.076	0.054	0.177	5	27	47
21. Fernandina Beach, Florida	8720030	1.36	2.14	2.90	−0.142	−0.002	0.130	−13	11	33
22. Mayport, Florida	8720220/218[a]	2.02	2.86	3.70	−0.068	0.077	0.207	4	28	50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.146	7	24	38



Boon and Mitchell *2016*



...stations 5 (Galveston) and 6 (Rockport), which have the highest median rise rates of any station in this study at 5.46 mm/y and 6.11 mm/y, respectively (Table 2), **followed by station 16 (Norfolk) at 5.11 mm/y ...**

To improve our understanding of sea level rise, we need:

- New data on subsidence in VA that has high spatial resolution (ongoing research via CCRFR)
- Continue to monitor sea level changes so that we can improve projections
- Understand the pattern of changes in the Gulf Stream so that we can improve projections

Projected impacts to infrastructure

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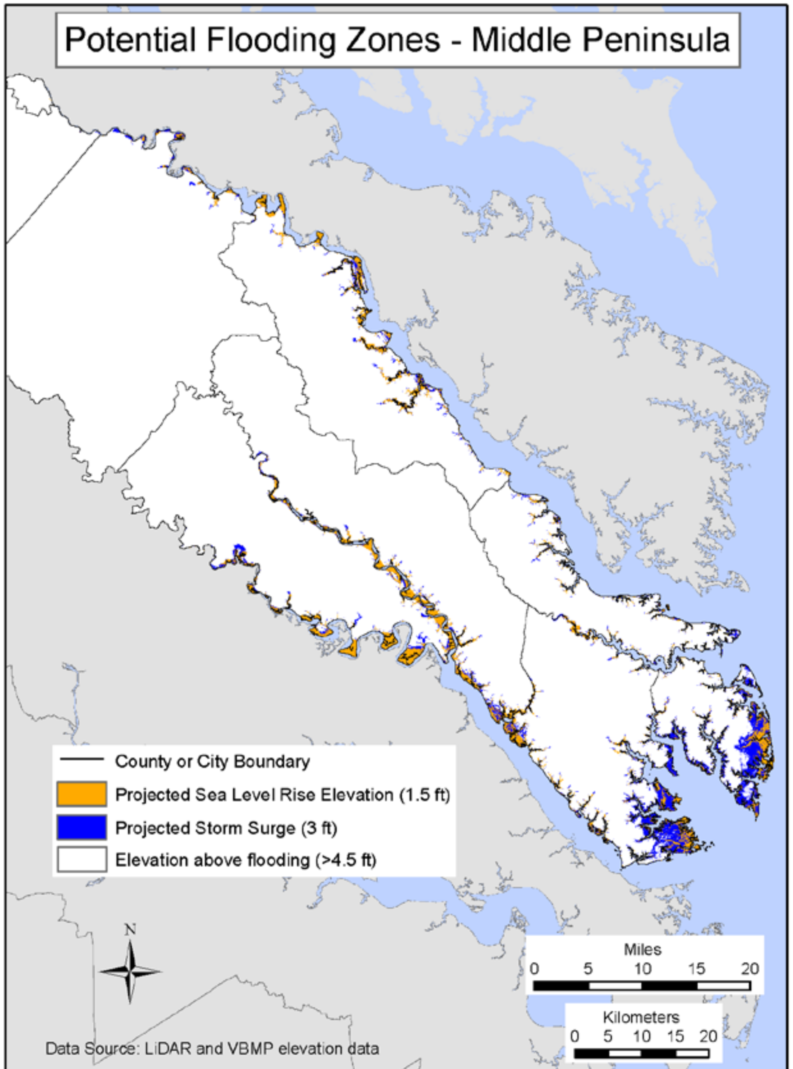
VIRGINIA INSTITUTE OF MARINE SCIENCE



Locality	Road miles flooded	Locality	Road miles flooded
Accomack *	326	Poquoson	38
Northampton	44	York*	24
Virginia Beach	289	Newport News	15
Chesapeake *	103	Hampton	50
Gloucester*	118	Portsmouth	51
Mathews	139	Norfolk	119
James City*	11	King William*	14

Data from Mitchell et al . 2013. Recurrent Flooding Study for Tidewater Virginia. Virginia Senate Document No. 3. Richmond, Virginia.

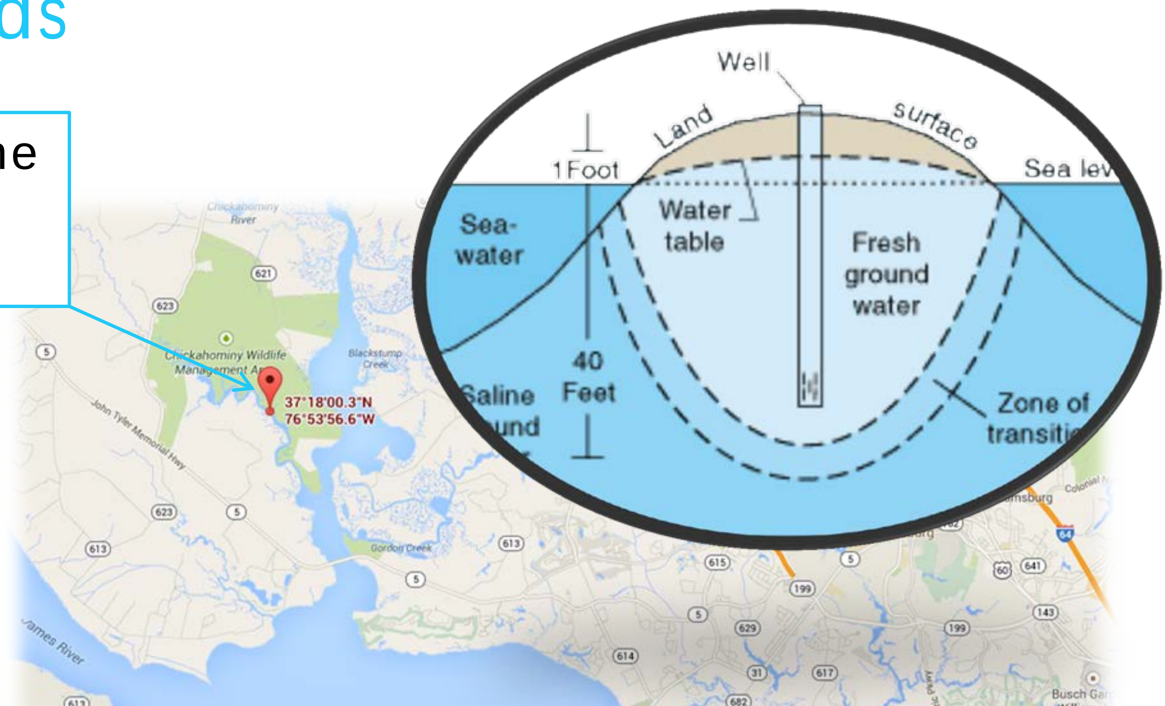
* Indicates that the area is predicted to see greater than 30% increase in population by 2030

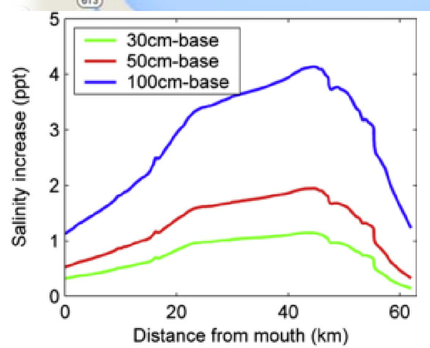
Saltwater intrusion into drinking water and agricultural fields

Water from above the dam is used for drinking water

With a **~1 ft** rise in sea level, salinity is projected to exceed drinking standards **11 days** out of the year

With a **~3ft** rise in sea level salinity is projected to exceed drinking standards **71 days** out of the year





Rice et al. 2012. Assessment of salinity intrusion in the James and Chickahominy Rivers as a result of simulated sea level rise in the Chesapeake Bay

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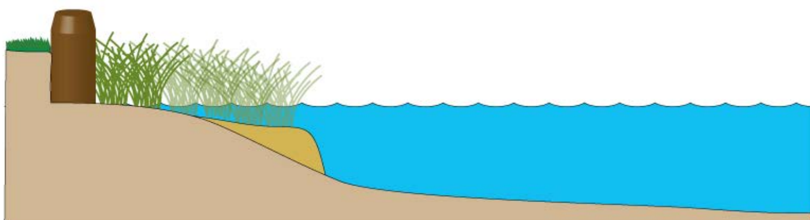
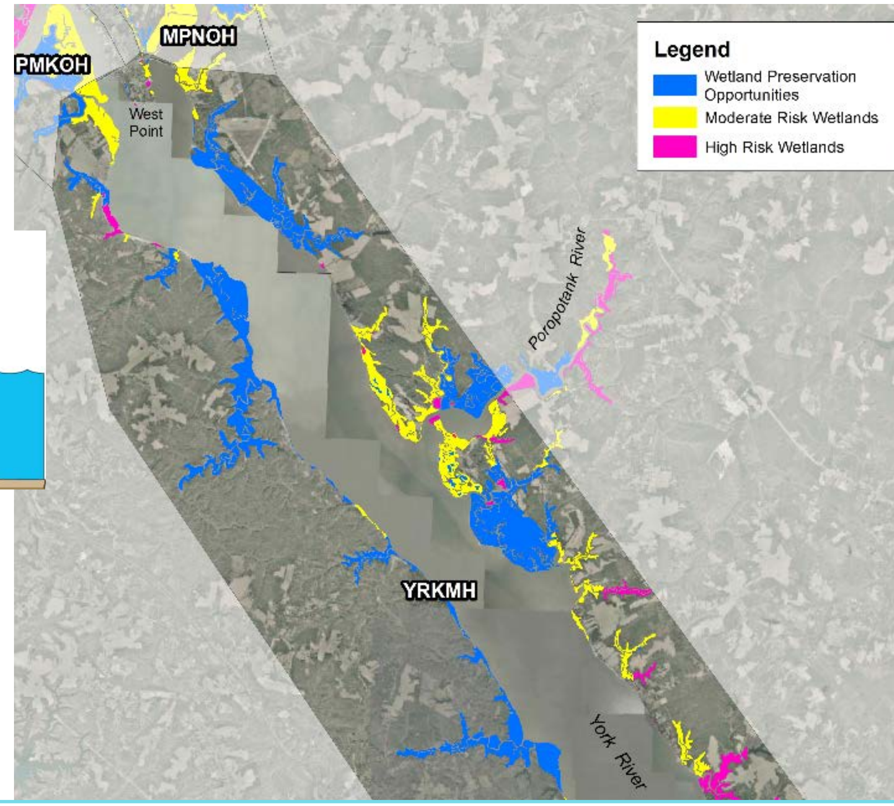
Impacts to marshes

Marshes are at high risk when:

1. They can't retreat landward due to shoreline structures



2. They can't retreat landward due to the height of the bank



With a 2 ft increase in sea level: **Nearly 40%** of Virginia marshes are vulnerable to SLR due to adjacent development

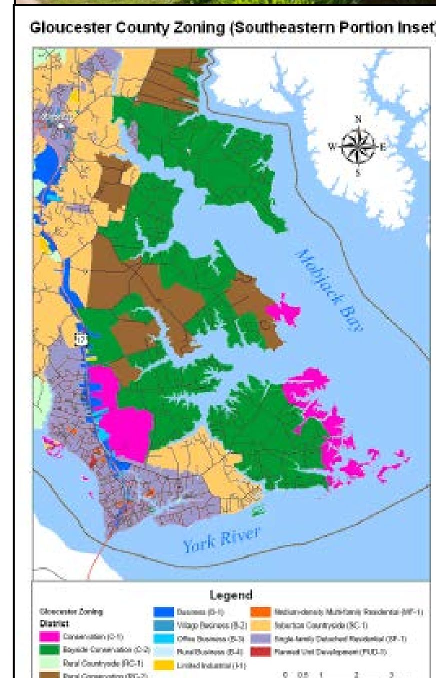
Bilkovic et al. 2009 Vulnerability of shallow tidal water habitats in Virginia to climate change

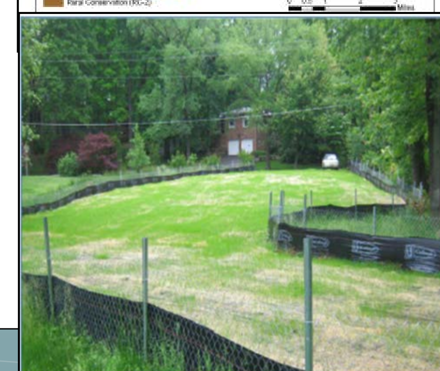
To better understand the impacts of sea level rise & flooding, we need:

- Better data on where flooding currently occurs and how that will interact with sea level rise
- Additional assessments of how flooding affects the human and economic health of the region

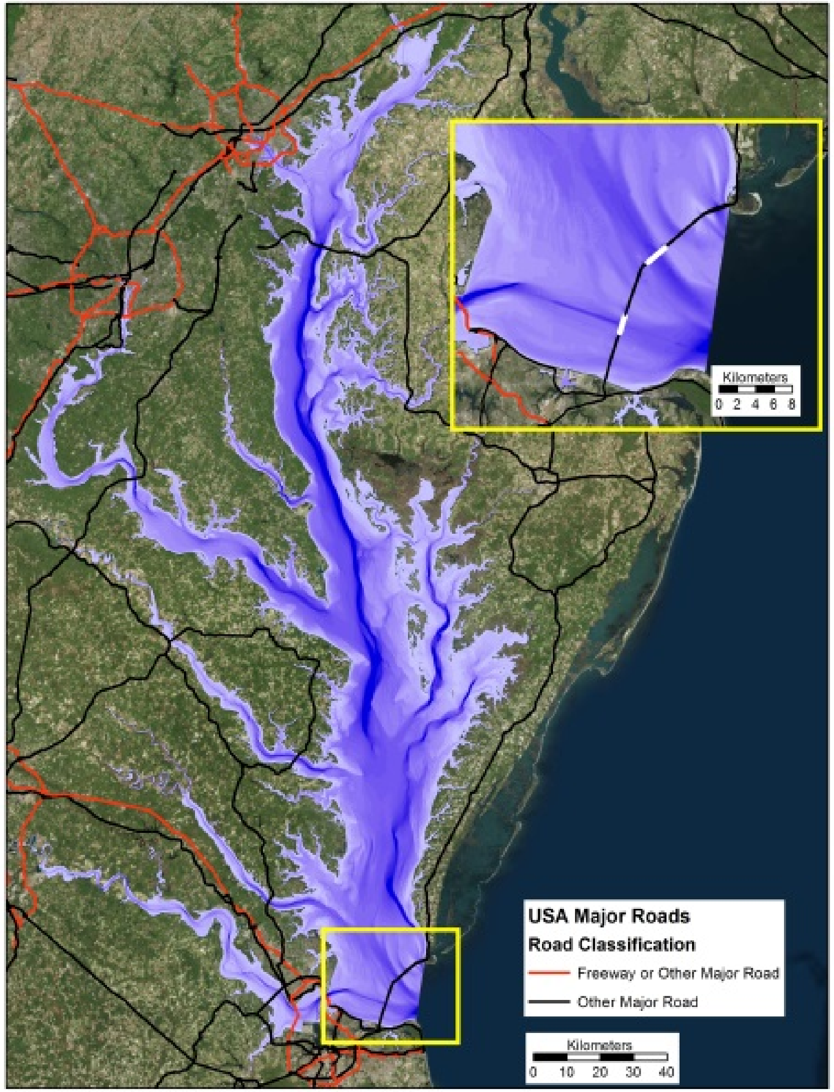
How do we adapt?

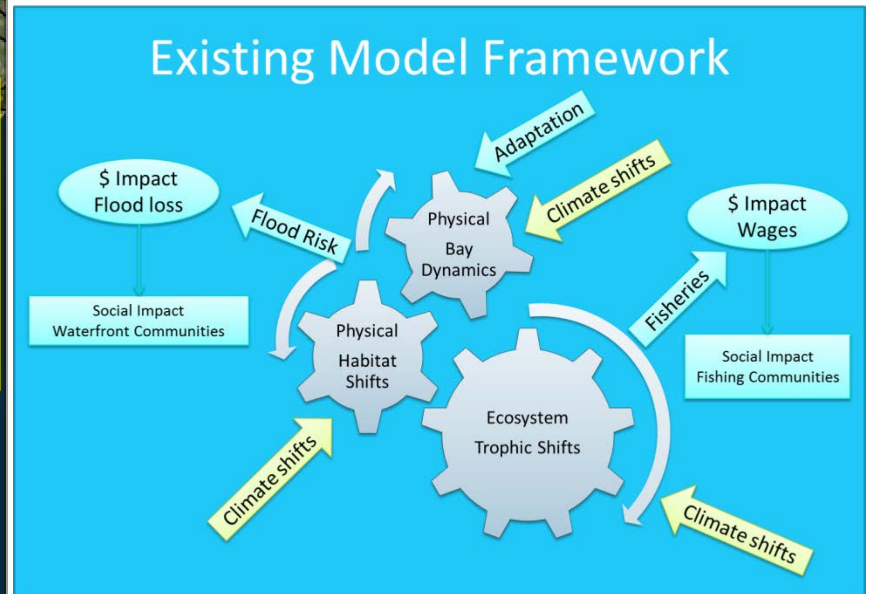
- In Virginia, most adaptation has been done at the individual or locality level
- This may not be sufficient for future flood projections
- Adaptation needs to address tidal waters, river waters and precipitation management
  - Water management needs to be holistically integrated into every aspect of our communities



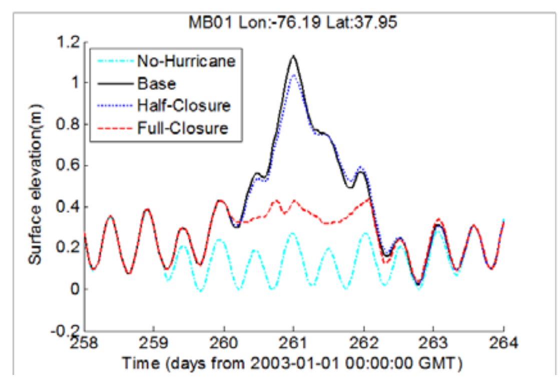


Chesapeake Bay sustainability project





Hurricane Isabel



Collaborators: Versar,Inc, National Oceanic and Atmospheric Administration, VCPC

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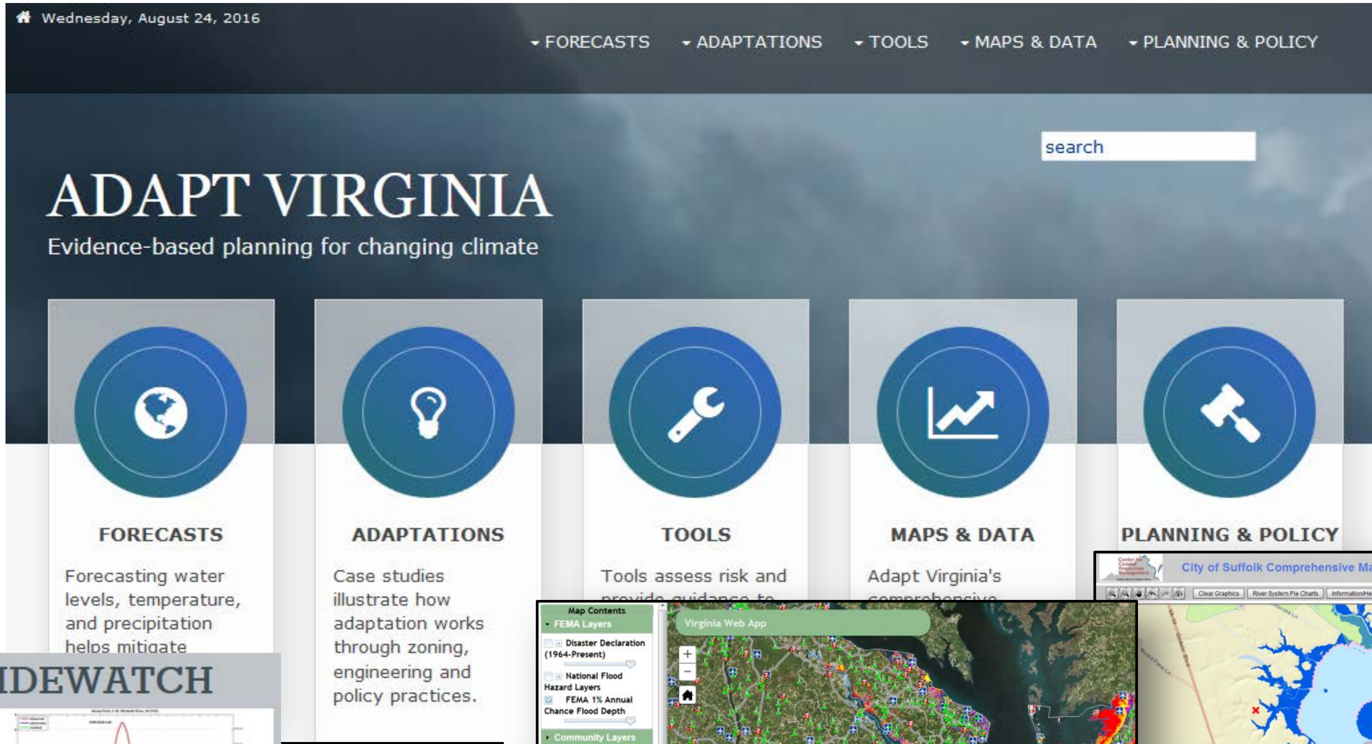
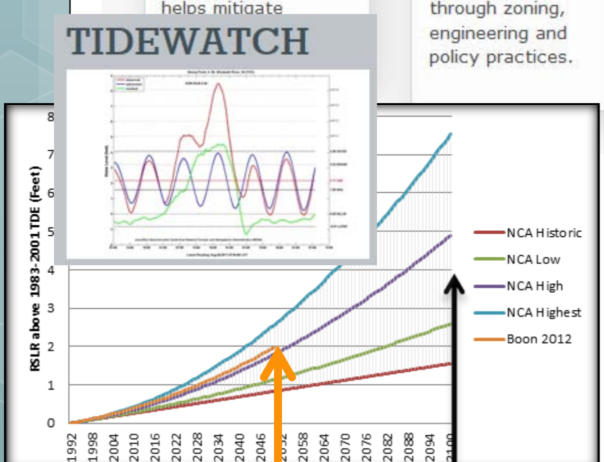
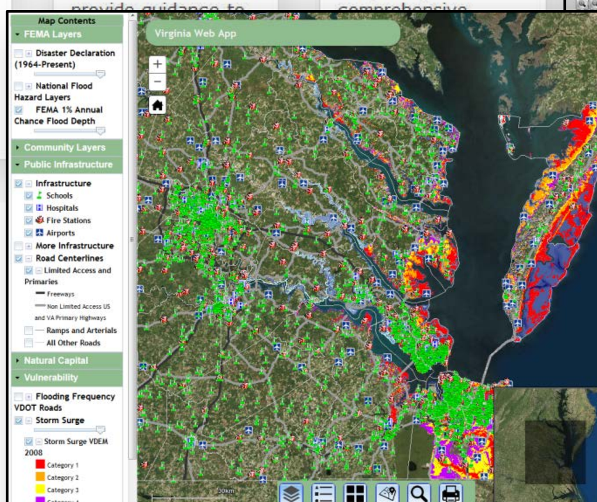
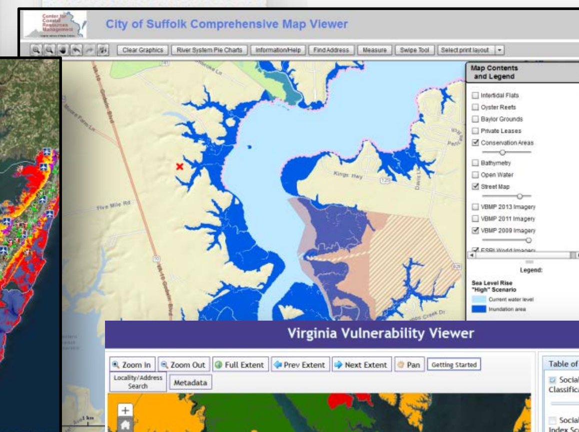
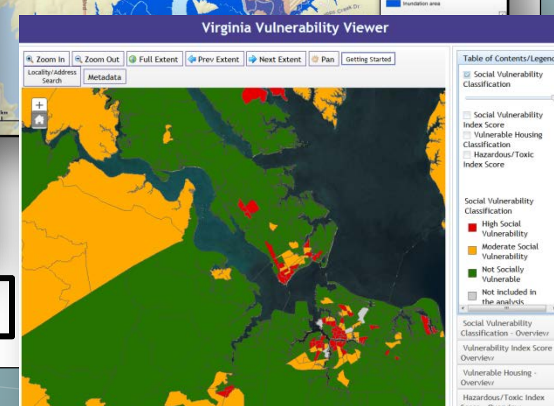
William & Mary Public Policy











Long-term projection: based on National Climate Model

Mid-term projection: based on analysis of tide gauge data

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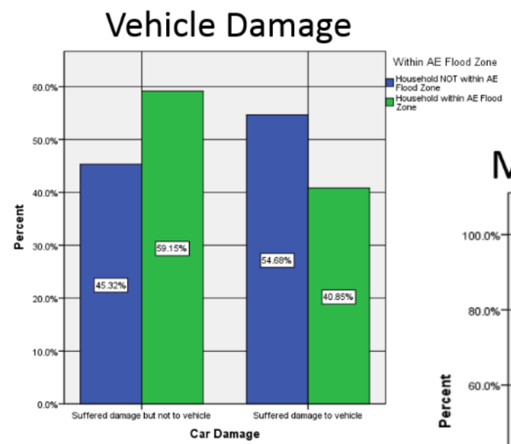
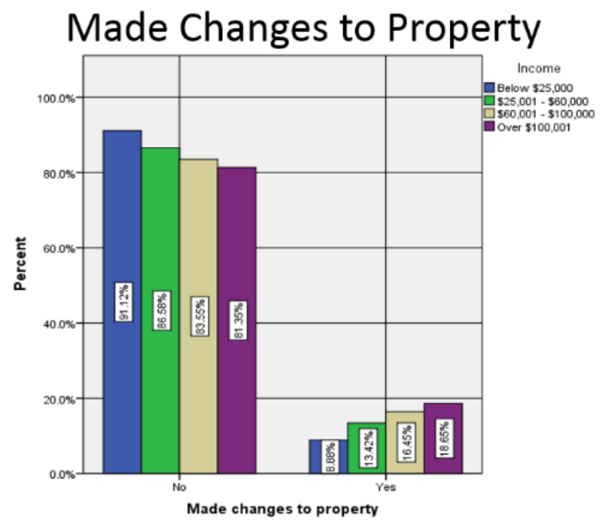
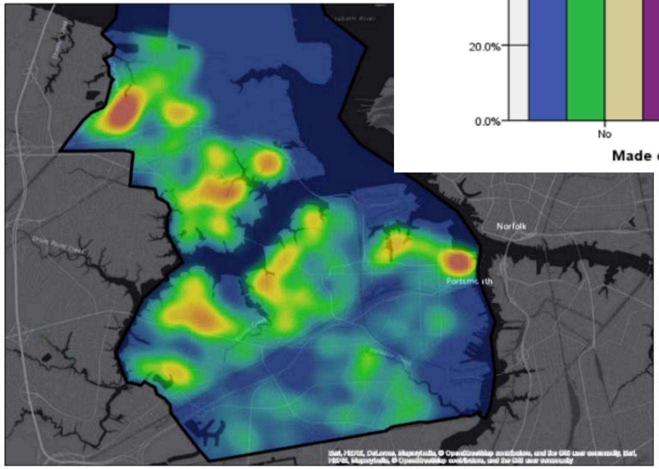
Assessing and Mapping Household Adaptation Behavior in Response to Recurrent Flooding

- Understanding citizen adaptation behavior to support local government comprehensive planning.
- Study evaluated experiences, responses, perceptions, responsibility to act and medical (asthma) variable







Behr, Diaz, McLeod (ODU/VMASC)

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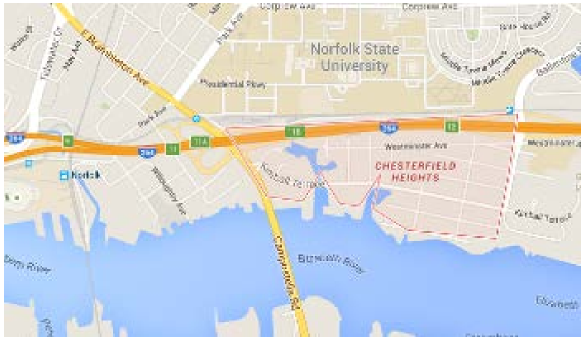
Neighborhood Resiliency: Innovative Water Management for Neighborhood Communities

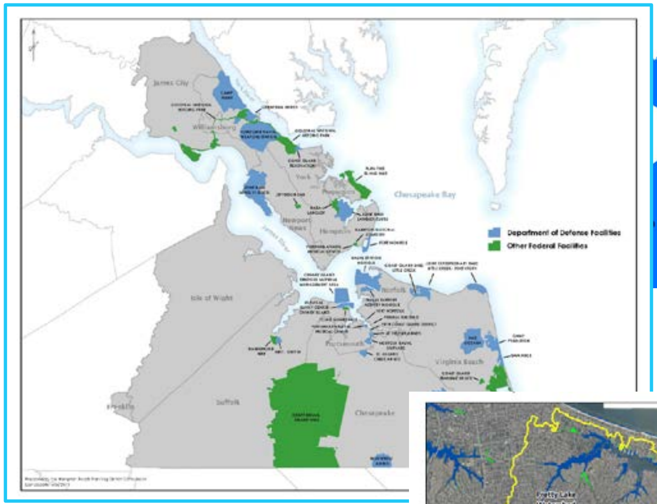
- Multi-disciplinary senior design projects focused on neighborhood solutions to curtail flooding.
- Completed studies include: Chesterfield Heights and the Hague
- Led to collaborations with Norfolk, Dutch Dialogues, and HUD NDRC

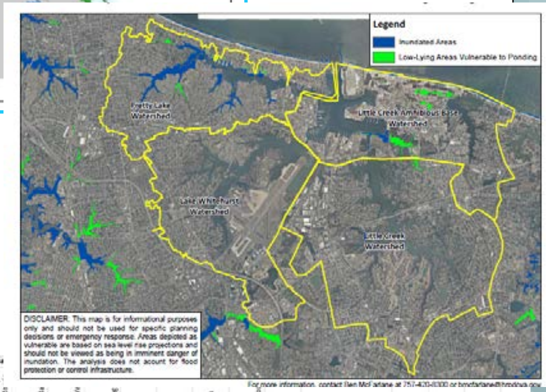


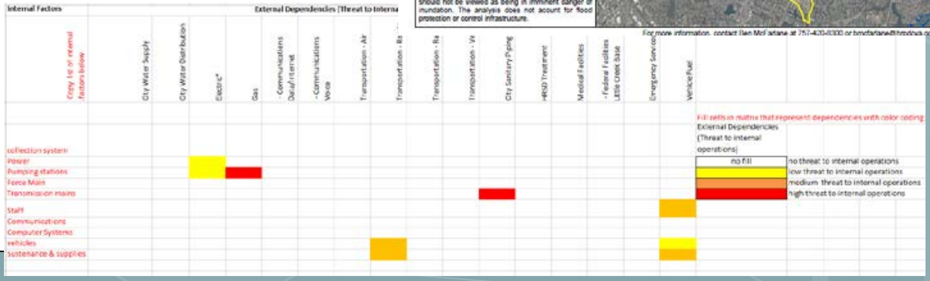
Erten Unal (ODU), Andrews (Hampton University) + VASG & Wetlands Watch

Infrastructure Analysis Support for the Hampton Roads Pilot Project

- Focused on adaptive planning for infrastructure projects and public health impacts related to sea level rise in the Hampton Roads Region as part of the Intergovernmental Pilot Project.







Considine & Becker (ODU)

CCRFR

To help us adapt to increased flooding pressures, we need:

- Improved short-term projections of water levels throughout the Bay
- Models that allow us to evaluate management options before they are put on the ground
- Data with regards to economic, infrastructure, and health impacts and more

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William & Mary Law School
Virginia Coastal Policy Center

Old Dominion University
Idea Fusion

CCRFR

Background on the Center

- 2016 General Assembly Authorization (HB 903) & Climate Change & Resiliency Update Commission Priority
- Leverage complimentary strengths of ODU + VIMS/W&M
- Support and enable decision making by local planners & emergency managers
- Provide coordinated research & technical support in one-stop-shop for stakeholders to obtain information related to flooding resiliency.
- Leverage CCRFR to bring funding to Virginia.

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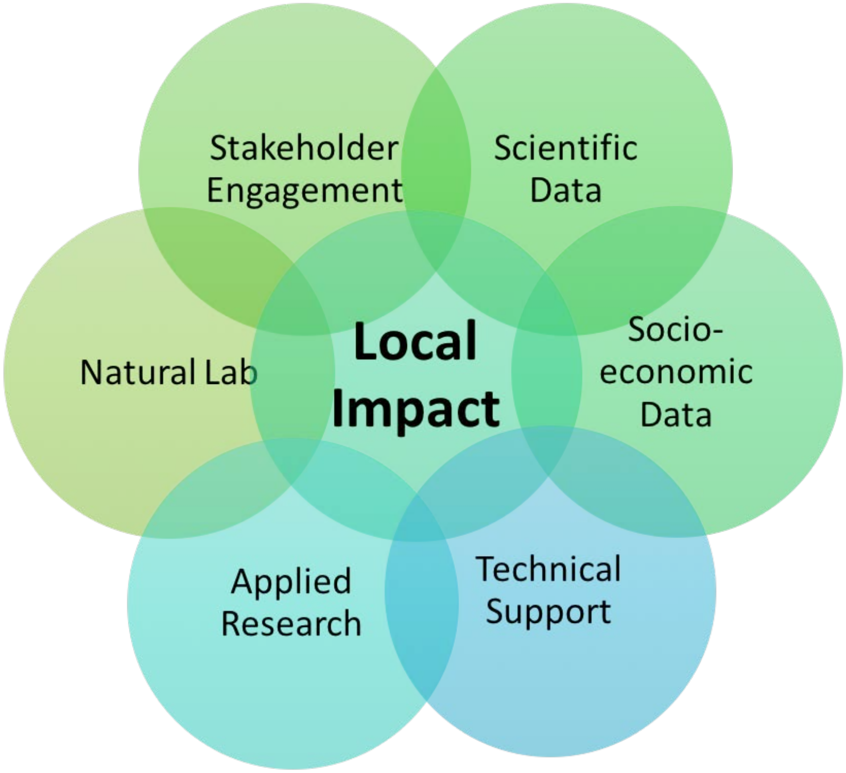
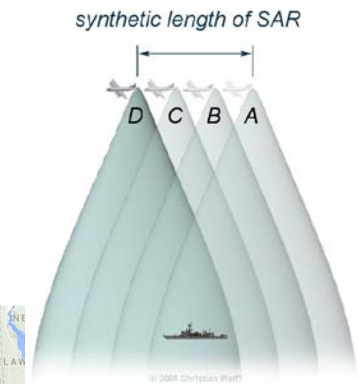
Ongoing CCRFR Projects

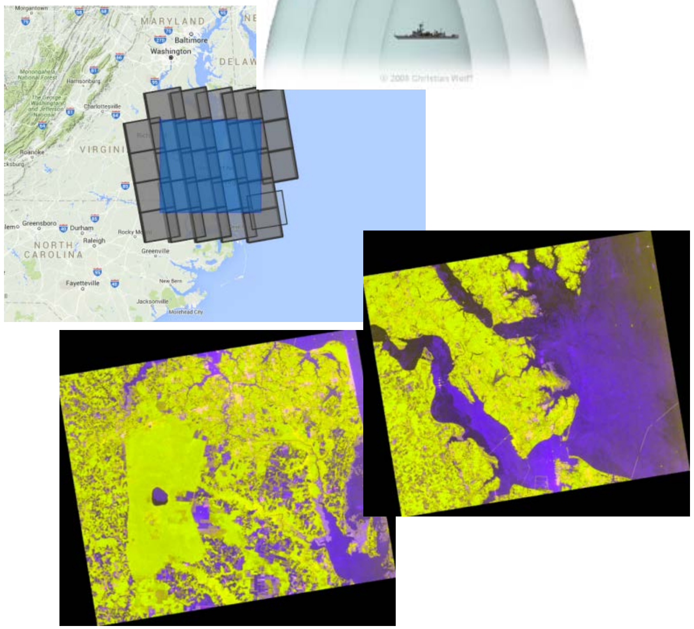


- Localized Subsidence
- Risk Communication Strategies
- Tourism Resilience
- Economic Impact Analysis
- Street Level Flood Modeling
- Enhanced TideWatch
- Liaisons with federal research partners & local convener
- More Coming Soon

Subsidence: Satellite InSAR Analysis



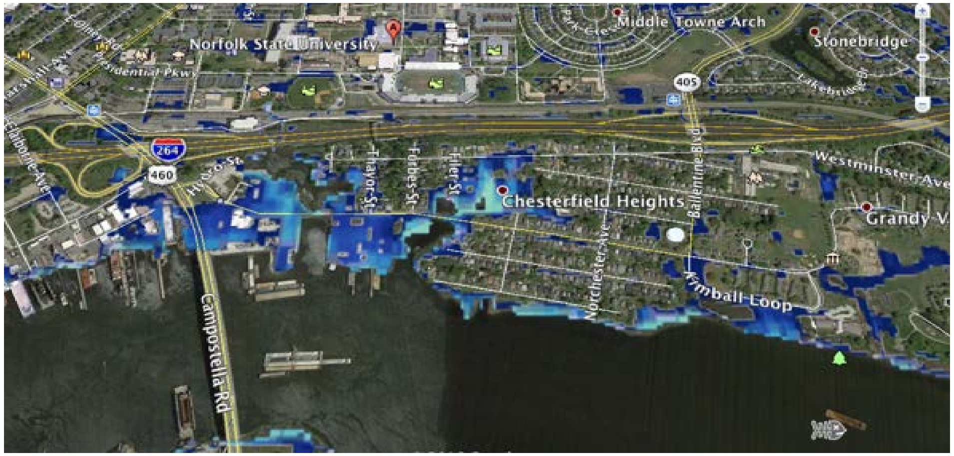
- **Questions:**
  - What does the subsidence map look like now?
  - How have these rates changed?
  - Is there greater spatial variability than indicated by this map.
- **InSAR:**
  - SAR: side looking radar which utilizes flight path to simulate antenna for hi res imagry
  - InSAR: uses 2+ images to estimate deformation or elevation
  - HR Data Avail: 2006-2011



- **Goal:** Generate improved localized subsidence map for HR showing current trends w/ uncertainty and resolution in order of 10s of meters.

Risk Communication Strategies

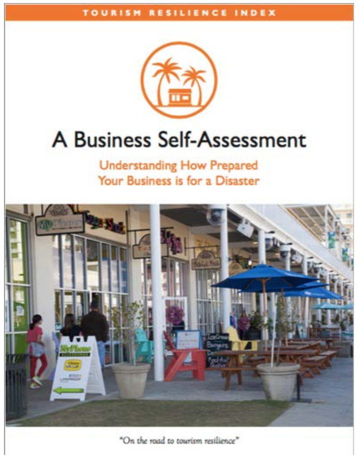
- Bringing together previous research on nuisance flooding communication & structured public involvement (IPP Case Study) with street level storm surge modeling capabilities and emergency manager feedback.
- Using innovative gaming strategies, to analyze and then enhance flood risk communication with specific groups of stakeholders using data from VIMS street level storm surge models.



Considine, Yusuf, Covi (ODU) with Loftis (VIMS) & Local EM & GIS Staff

Tourism Resilience

- Modeled on a similar tool, the Tourism Resilience Index, developed by Mississippi – Alabama Sea Grant
- Needs Assessment & Info Gathering: In-person survey, with owners of tourism-related companies to determine current level of resilience and assess areas for improvement.
- Build Resiliency: Workshops, Coastal Virginia TRI, VB Tourism Resilience Assessment
- Policy Analysis: VCPC analyzing current policies for resilience opportunities



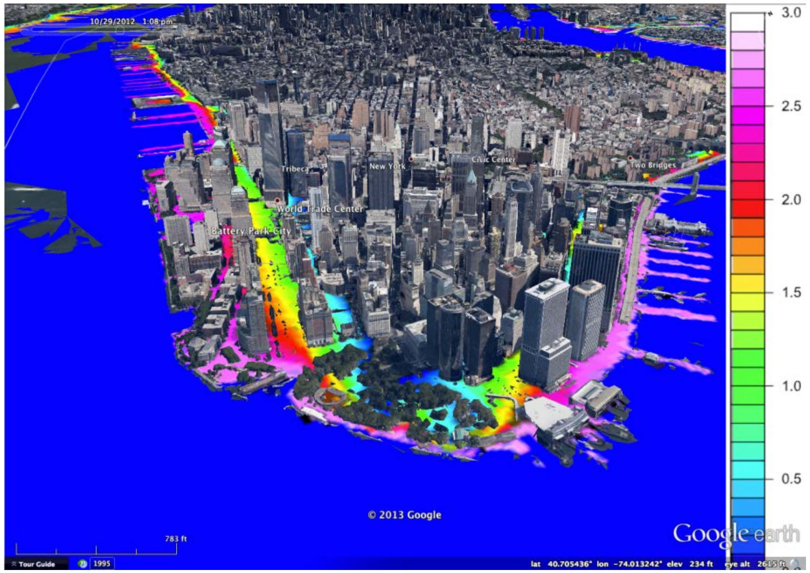
Usher, Covi, Yusuf, Steinhilber (ODU) & VCPC Students w/ VB EM

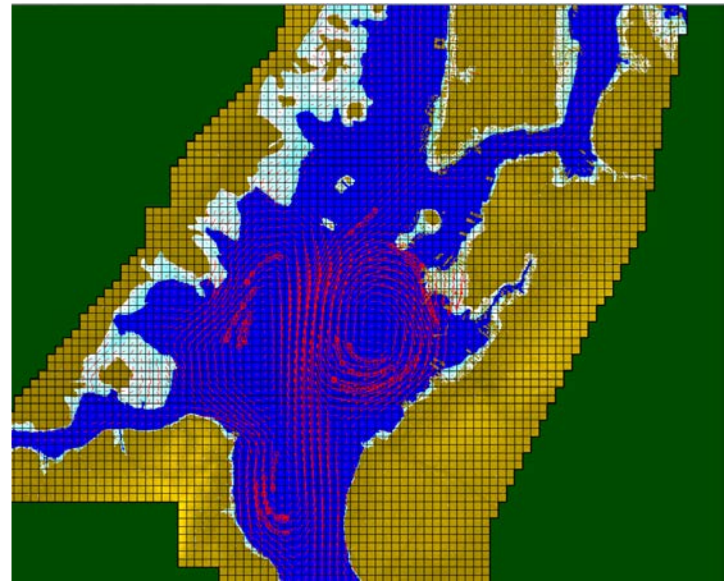
Ongoing Economic Impact Analysis

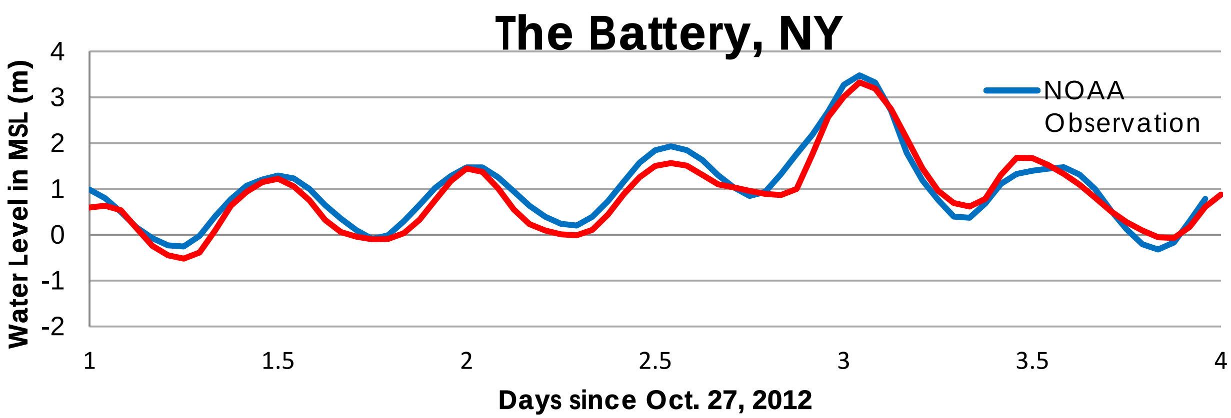
- Overtime create series of white papers & database to couple with VIMS & VMASC modeling.
- Partnerships with HREDA & others
- Ongoing:
  - Cluster analysis of potential water management cluster in Hampton Roads,
  - Convening others conducting impact research to coordinate and communicate needs, etc.
- Sample Future Topics:
  - Resilient Zoning & commercial development
  - Flood risk (or perceived risk) impact on firm attraction & relocation
  - Individual and regional participation in NFIP program

Filer (ODU) with UVA & W&M faculty

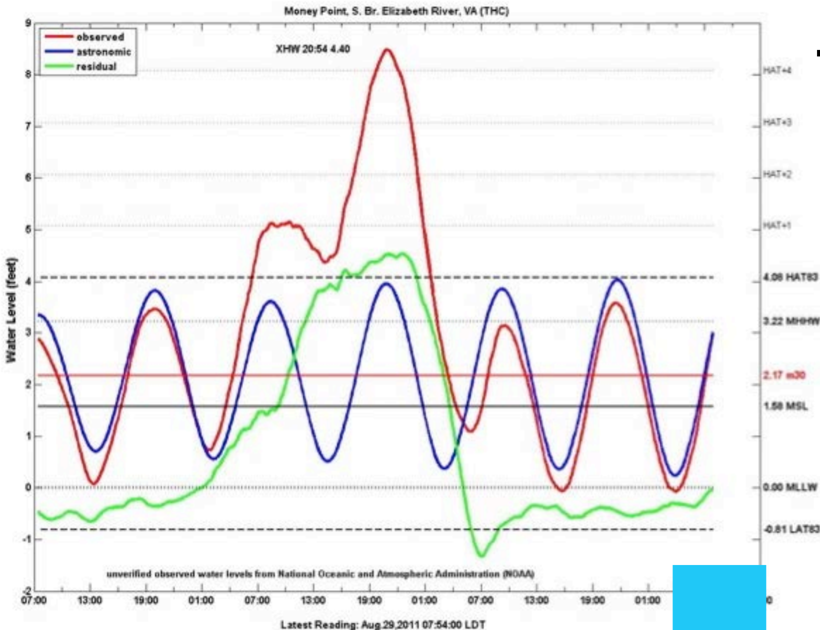
Street Level Flooding Model







Harry V. Wang[1], Derek Loftis[1], David Forrest[1], Aron Roland[2] Zhuo Liu[1] and Joseph Zhang[1]

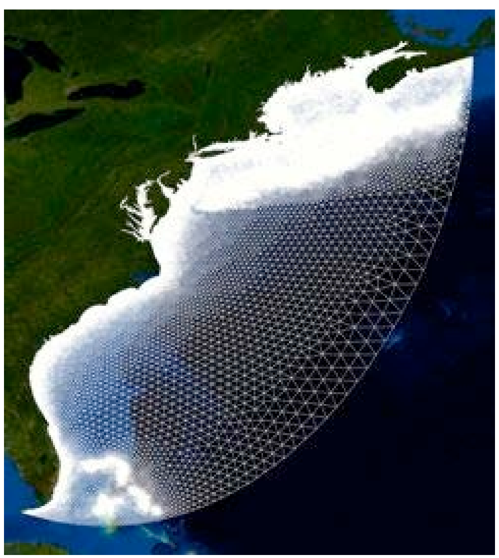


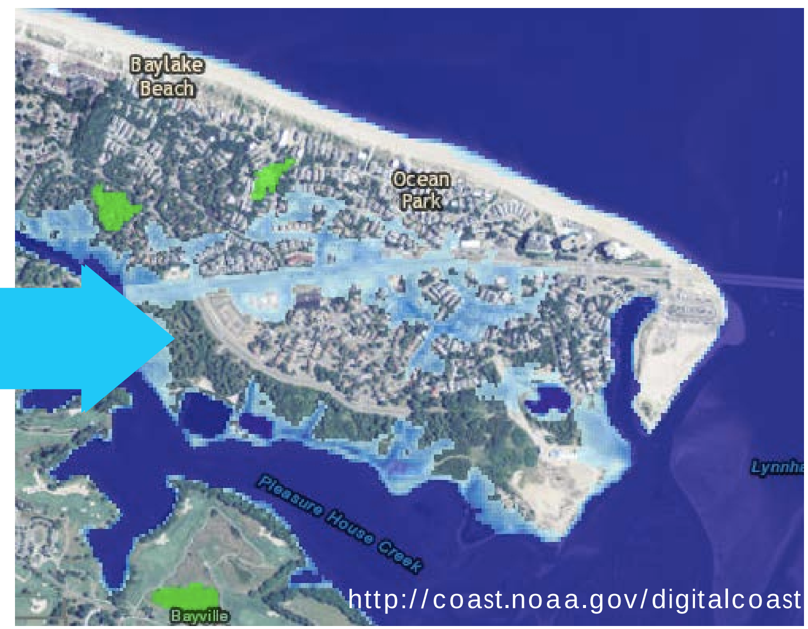
Tidewatch expansion

Predicted (astronomical) tide is the daily change in water level produced by the gravitational interactions of the earth, moon, and sun.

Observed water level (NOAA tide gauge data) – includes storm surge

Difference between predicted and observed water level – weather tide





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Questions?

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