Tidal Marsh Migration In Response to Sea Level Rise

A Chesapeake Bay Trust Project

CRWG Workgroup

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Project Scope

- This project will develop a methodology for using results from marsh migration models combined with social, landuse, and environmental data to inform marsh management, conservation, and restoration under sea level rise
- This project will provide a dataset of available information (scale, scope, etc) that could help inform management decisions

- This project will not run any marsh migration models
- This project will not result in the methodology being applied across the Chesapeake Bay

Project Tasks/Deliverables

1. Identification of data relevant to assessing marsh longevity, condition, migration potential, etc.
   - 111+ data sources identified
   - 14 topics, including sea level rise, natural resources, landuse, and social/economic data
   - Topics subdivided into >50 categories of data
   - Presented in table form and metadata sheets
2. Literature review of marsh migration models
   - Models of marsh response, not just migration
   - Focus on synthesis of available data for models
3. Development of methodology for using marsh migration models to identify marsh restoration/preservation/conservation opportunities ***using 3 target areas***

Shoreline, Sea Level Rise, and Marsh Migration Data for Wetland Restoration Targeting Metadata Fact Sheet

Topic: Distribution of Natural Resources

Category: Maritime Forest

Data Name: Coastal Maritime Forests in Virginia – Delineation and Distribution

Data Source: Center for Coastal Resources Management (CCRM), Virginia Institute of Marine Science (VIMS)

Data Type: Report with map

Resolution: 2 Feet

Geography Covered: Virginia

Date Range of Data: 2007

Overview:

The project had two major goals. The first builds on an earlier effort by the Virginia Department of Forestry, who delineated maritime forests using remote sensing techniques. Their project integrated land use and soils data to generate a map that defines potential boundaries of maritime forest. This study follows an identical approach with two major exceptions. The first is the soils data used in this study is mapped at a much finer scale. The second is this study has a field validation component that reviewed random sites around selected locations to ground-truth the remote sensing output. The Virginia Department of Forestry provided staff support from various regional offices to perform all field work. Ancillary data such as soils and aerial imagery were also used where wetland and dune habitat could be distinguished. The second major goal of this project was to compute, on a county-by-county basis, the amount of maritime forest cover present in each coastal locality, and the extent of maritime forests located within conservation lands. Boundaries for conserved lands data from VA DCR were used.

Methodology:

Delineation was generated for each county or city evaluated by digitizing and editing boundaries according to field recommendations while using maritime forest soils and 2002 VBMP high resolution imagery (2 ft resolution) for guidance. ArcMap® was used and shape files were generated. A separate review by the VADCR Division of Natural Heritage indicated an absence of coverage on the eastern shore barrier islands. These were added to the final map compositions using comparable image processing techniques, but no field validation. Referenced survey data provided by Natural Heritage Program provided a comfortable level of ground-truthing.

Available online? Yes

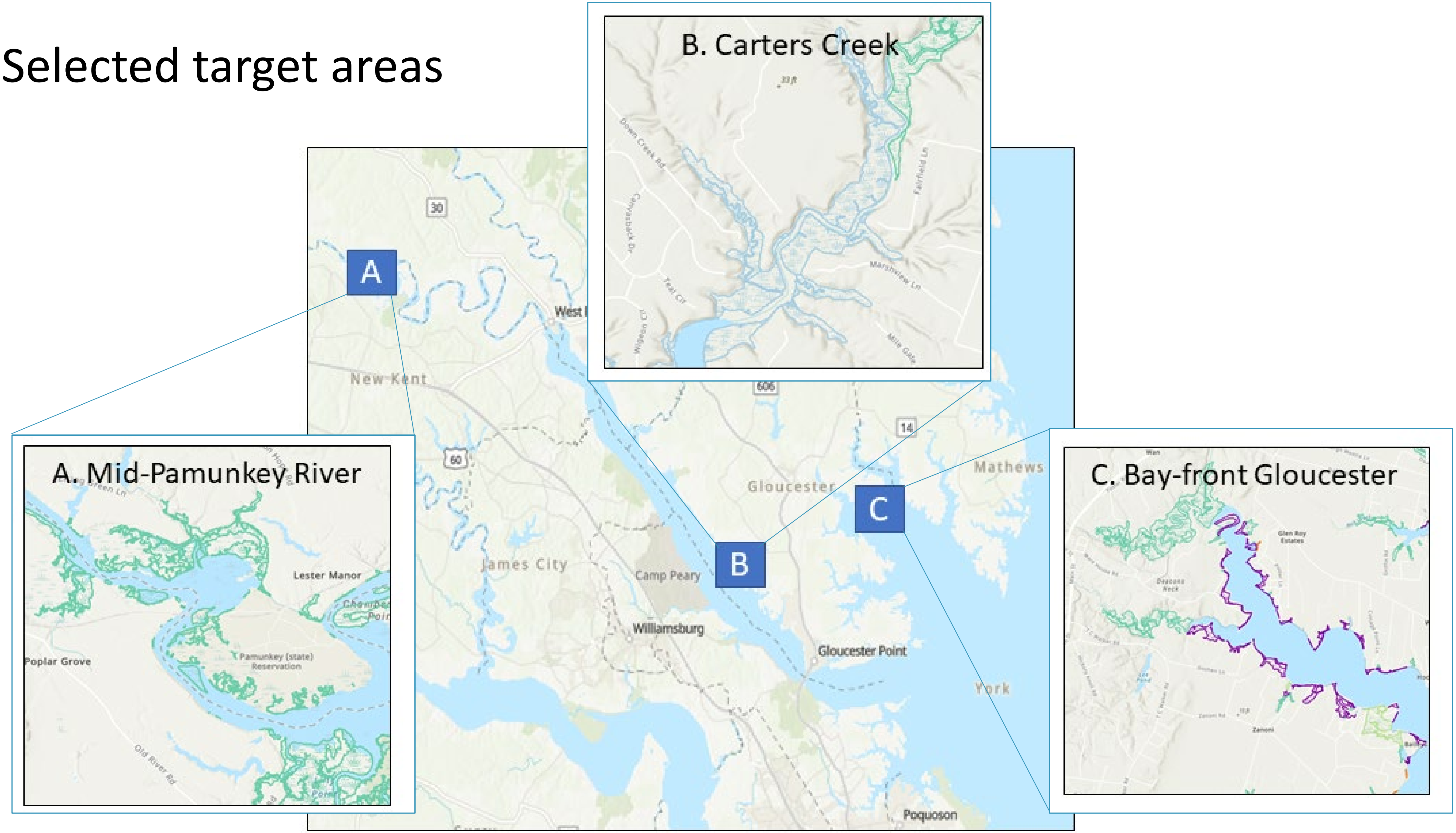
Data Link: https://scholarworks.wm.edu/cgi/viewcontent.cgi?article=1508&context=reports

Citation:

Berman, M., & Berquist, H. (2007) Coastal Maritime Forests in Virginia – Delineation and Distribution. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.21220/V5Q71P

Prepared by: The Center for Coastal Resources Management
Virginia Institute of Marine Science
William & Mary, Gloucester Point, VA
Current as of: September 2021

Selected target areas



Marsh Models

- **SLAMM 5.0 – Sea Level Affecting Marshes Model**
- Developed by Warren Pinnacle Consulting, Inc.
- Simulates dominant processes involved in wetland conversion under different SLR scenarios (inundation, erosion, accretion, soil saturation and barrier island overwash).
- Uses a decision tree incorporating geometric and qualitative relationships to represent transfer among coastal classes.

- **InVEST - Integrated Valuation of Ecosystem Services and Tradeoffs**
- A suite of models used to map and value the goods and services from nature.
- InVEST models are based on production functions that define how changes in an ecosystem's structure and function are likely to affect the flows and values of ecosystem services across a land- or a seascape.

- **NOAA – Sea Level Rise Viewer: Marsh Migration**
- It maps sea level rise marsh migration using a process developed by the NOAA Office for Coastal Management.
- It shows potential impacts to marsh environments from sea level rise for the Sea Level Rise Viewer.
- Generally, this process can be described as a modified bathtub approach that attempts to account for local and regional tidal variability.
- These data represent the potential distribution of each wetland type based on their elevation and how frequently they may be inundated under potential future SLR scenarios, from 0 to 10ft of SLR.

- **ETM – Evolution of Tidal Marsh**
- Developed by the CCRM, VIMS.
- Data layers represent the land that is encompassed by the average tidal range (2 ft) as sea level rises in the Virginia coastal region.
- Data layers represent each 2-foot range of elevation incremented by 0.5 ft (e.g. 0-2 ft, 0.5-2.5 ft, 1-3 ft, etc.) with the current land cover that exists in that range.

- **TMM – Tidal Marsh Model**
- Developed by the CCRM, VIMS, within the SCHISM framework (Semi-implicit Cross-scale Hydroscience Integrated System Model) – Hydrodynamic simulations
- TMM simulates marsh migration under the joint influence from tides, wind waves, sediment transport, precipitation, and sea level rise.
- TMM accounts for shoreline bank erosion, upland erosion inputs at the upland-marsh edge, marsh vertical accretion through mineral sediment deposition, and marsh landward migration under changing sea levels with constraints from physical barriers (e.g. development, shoreline structures).

Sea-level rise (SLR) scenarios

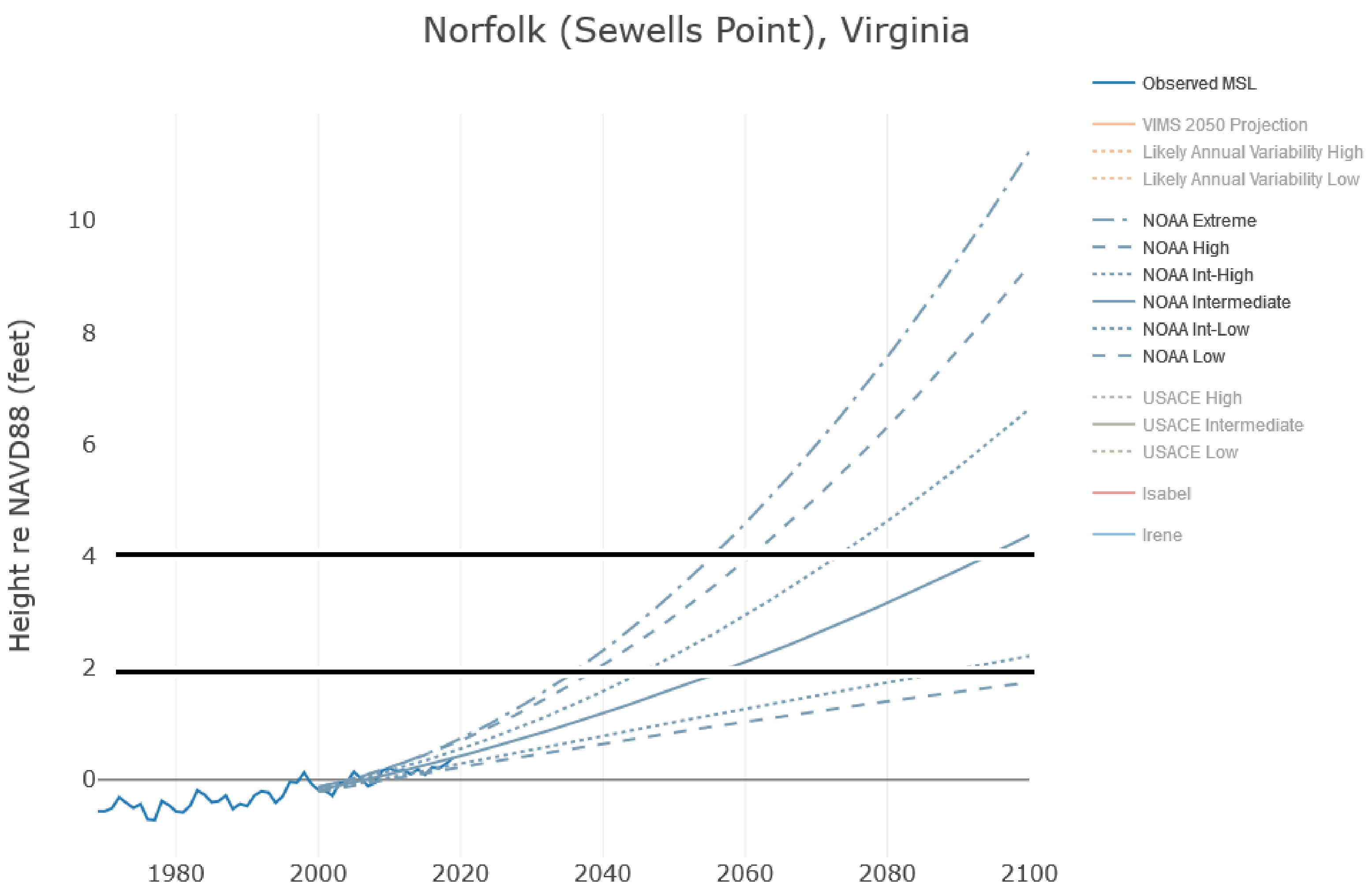
2 water levels were selected to allow for consistent comparison across models

The selected water levels were:

- 2 ft increase in MSL
- 4 ft increase in MSL

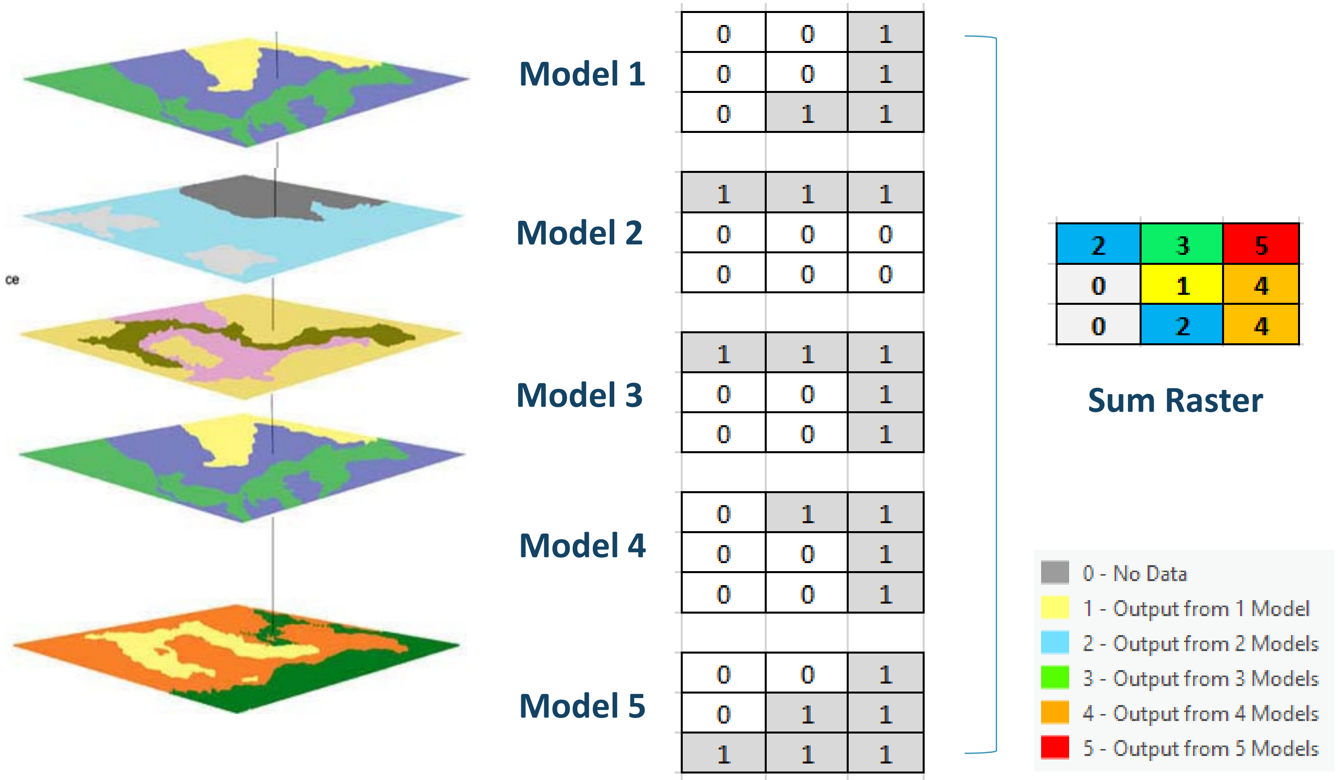
above the current tidal datum

We compared water levels rather than SLR scenarios since the scenarios differed between models so selecting a given projection and/or year would result in inconsistent water level comparisons



Methodology

1. Data acquisition
2. Data formatting
3. Selection of the model outputs corresponding to the two SLR scenarios
4. Clip the data to the study areas
5. Remove existing marsh (using Tidal Marsh Inventory) to focus on migrated marsh
6. Run different geoprocessing tools in ArcGIS Pro to generate a non-weighted sum raster

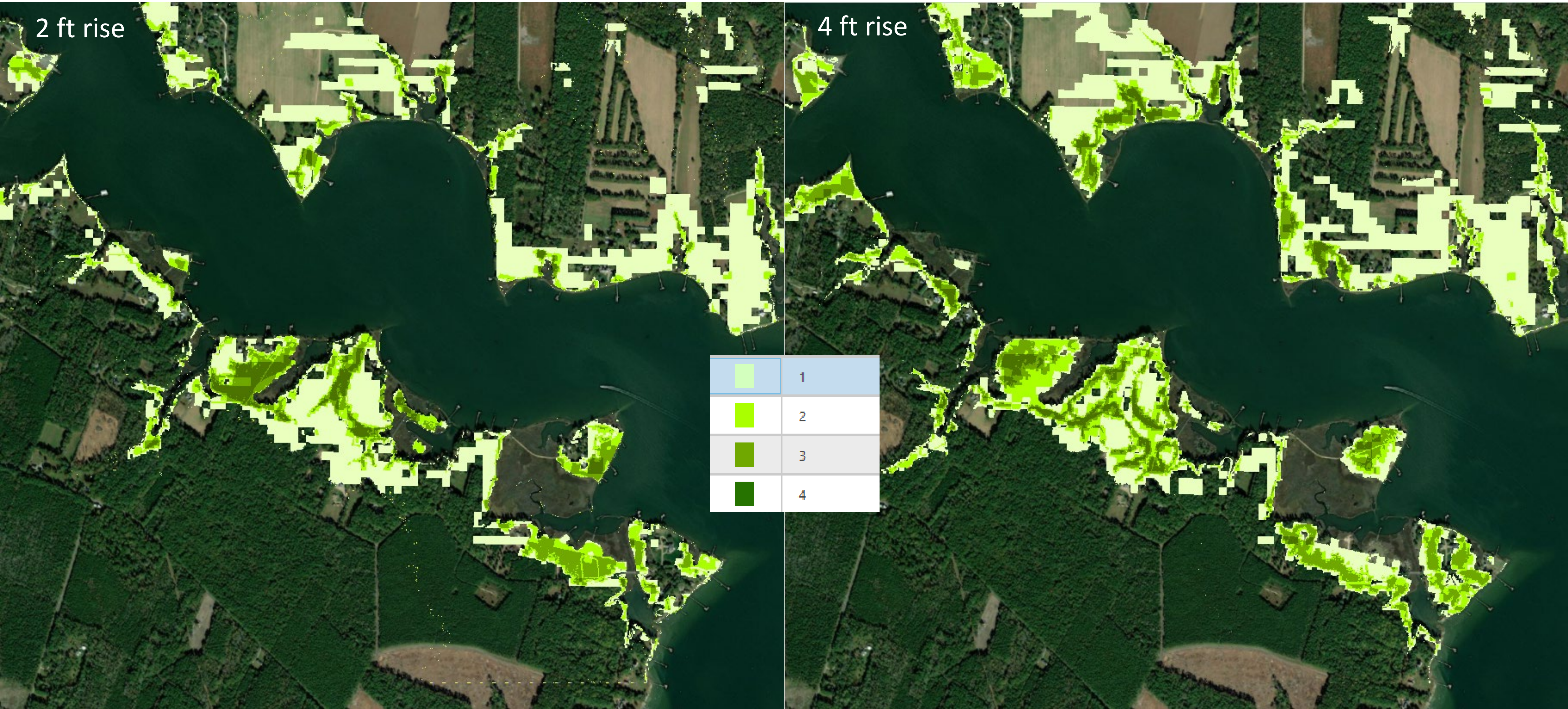


SUM RASTER: each cell has the value that represents the sum of models that predict marsh presence at that specific location.

Different Approaches:

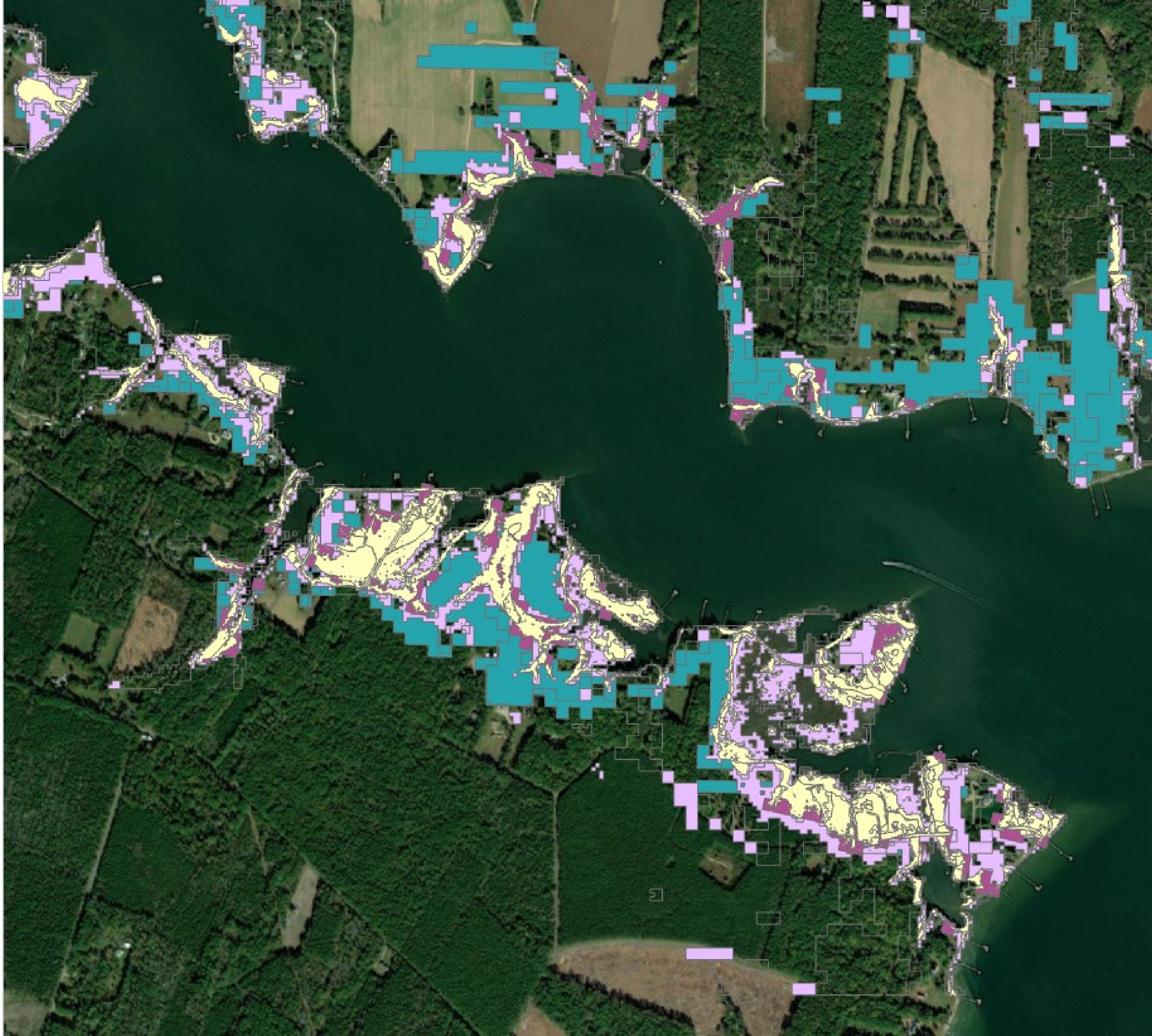
- **Example 1**: ETM and InVEST projected marsh migration area includes only the "natural" land use categories (i.e., excludes development).
- **Example 2:** ETM and InVEST projected marsh migration area includes all the land use categories.

Site C: Bay Front, Example 1



Site C: Bay-front 2 ft, example 1

- ETM
- INVEST
- NOAA
- SLAMM



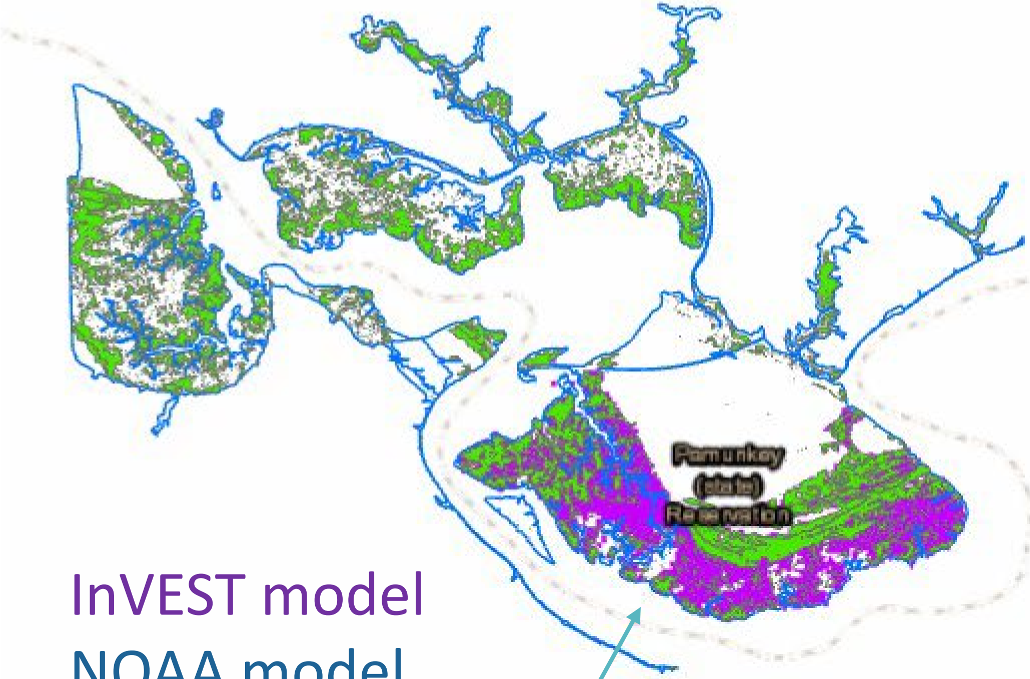
- **Example 1**: ETM and InVEST projected marsh migration area includes only the "natural" land use categories (i.e., excludes development).
- **Example 2:** ETM and InVEST projected marsh migration area includes all the land use categories.

EXAMPLE - 1		Area (acres)		
Scenario	Model	Pamunkey	Ware	Carter
2ft	SLAMM A1B	70.9	317.1	64.1
4ft	SLAMM 1pt5	66.2	354.8	63.8
2ft	**InVEST Int 2061**	**478.9**	**102.5**	**69.5**
4ft	**InVEST IntHigh 2075**	**185.3**	**179.9**	**96.4**
2ft	NOAA mm20	516.7	165.3	103.9
4ft	NOAA mm40	176.8	198.1	115.9
2ft	**ETM_2ft**	**91**	**88.9**	**26.3**
4ft	**ETM_4ft**	**107.3**	**133.2**	**29.2**
2ft	TMM Intermediate	n/a	n/a	24.9
4ft	TMM Extreme	n/a	n/a	27.5

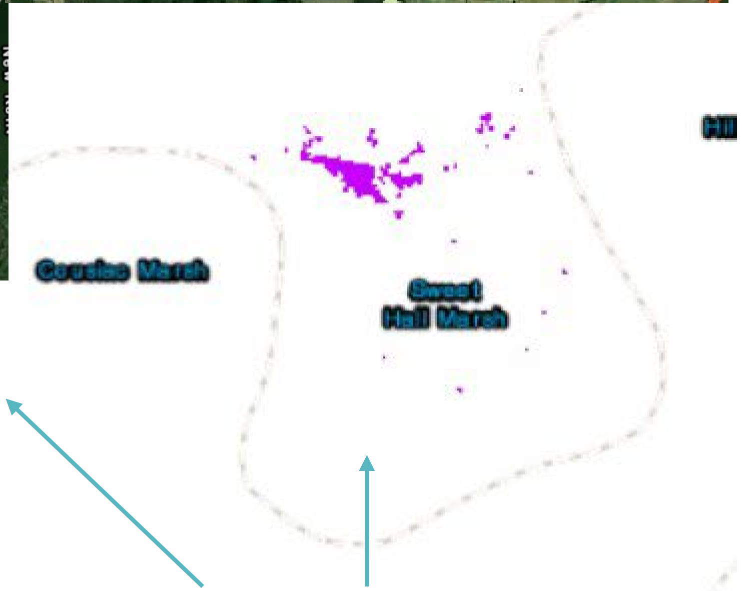
EXAMPLE - 2		Area (acres)		
Scenario	Model	Pamunkey	Ware	Carter
2ft	SLAMM A1B	70.9	317.1	64.1
4ft	SLAMM 1pt5	66.2	354.8	63.8
2ft	**InVEST Int 2061**	**480.8**	**103.1**	**69.5**
4ft	**InVEST IntHigh 2075**	**190.4**	**183.1**	**96.4**
2ft	NOAA mm20	516.7	165.3	103.9
4ft	NOAA mm40	176.8	198.1	115.9
2ft	**ETM_2ft**	**258.4**	**132.3**	**83.5**
4ft	**ETM_4ft**	**134.8**	**160.7**	**56.4**
2ft	TMM Intermediate	n/a	n/a	24.9
4ft	TMM Extreme	n/a	n/a	27.5

Even if the cumulative areal totals agree somewhat, the spatial overlap of the models may not.
The following slides show that there are many areas where the models do not coincide

Note about InVEST model



InVEST model
NOAA model



These 2 marshes have large migrated marsh areas at 2 ft SLR

That area is currently tidal swamp

These marshes do not – and do not have tidal swamp in them

Model comparison – Data differences

MODEL	Resolution (land use)	Resolution (elevation)	Elevation source	Vertical datum	Marsh Source
SLAMM	30m x 30m	10m x 10m	CUDEM	Mean Tide Level	NWI (1988 - 1992)
InVEST	30m x 30m	3m x 3m	CUDEM	MHHW	VIMS TMI (Berman et al. 2016)
TMM	30m x 30m (C-CAP)	1m x 1m	CBTBDEM	NAVD88	VIMS TMI (2016)
NOAA	30m x 30m (C-CAP)	*	CUDEM	tidal datums	C-CAP?
ETM	1m x 1m (VGIN)	1m x 1m (lidar)	CBTBDEM	NAVD88	NWI and TMI

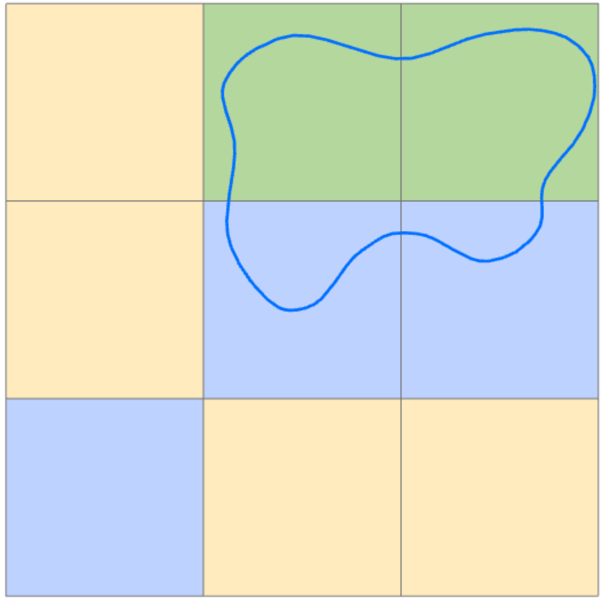
* These data were derived from the most recent elevation data available at the date of processing that met project specifications, the most recent VDatum tidal model data available at the date of processing, and 2011 CCAP Land Cover data.

CUDEM--continuously updated digital elevation model from NOAA; CBTBDEM--Chesapeake Bay topobathy digital elevation model from CoNED USGS

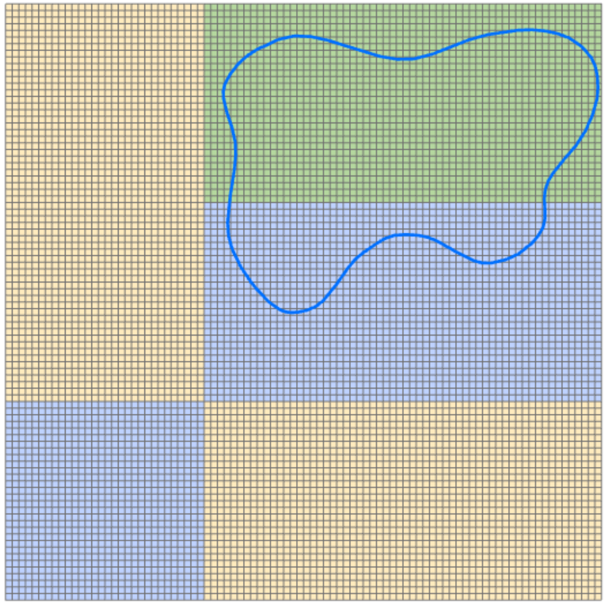
Cumulating the differences in resolutions from multiple datasets will add to the discrepancies between model outputs.

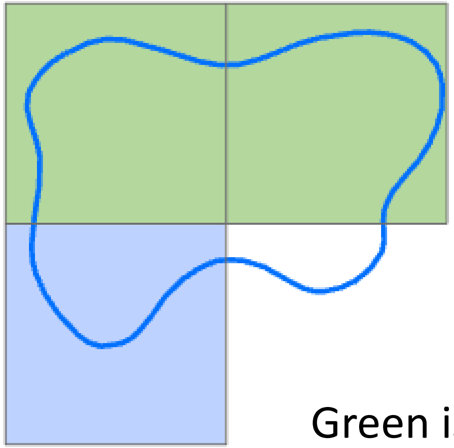
Model comparison – Resolution differences

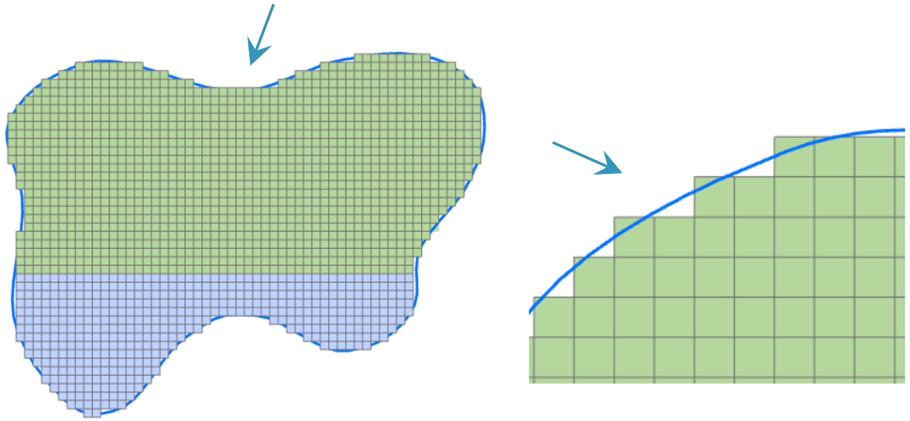
30m pixels (900 m^2)



1m pixels (1 m^2)







Dark blue polygon is 1707 m^2

Green is 1800 m^2
Blue is 900 m^2
Total is 2700 m^2

Difference
Green 30%
Blue 50%
Total 37%

Green is 1255 m^2
Blue is 449 m^2
Total is 1704 m^2

Model comparison – Assumption differences

MODEL NAME	SLAMM 5.0 – SEA LEVEL AFFECTING MARSHES MODEL	INVEST - INTEGRATED VALUATION OF ECOSYSTEM SERVICES AND TRADEOFFS	NOAA – SEA LEVEL RISE VIEWER: MARSH MIGRATION	ETM – EVOLUTION OF TIDAL MARSH	TMM – TIDAL MARSH MODEL
VERTICAL ACCRETION/SEDIMENTS PROCESSES INCLUDED	Yes (localized, assumed linear)	Yes (uses max. vertical accretion rate from Schuerch et al. 2018)	Yes	No	Yes (Based on SCHISM Sediment Model)
BARRIERS TO MIGRATION INCLUDED	Yes (development)	No	Yes (development)	Yes (shoreline structures captured in elevation data and developed areas can be removed)	Yes (development and shoreline structures)
STATIC/DYNAMIC MODEL?	Static	Static	Static	Static	Dynamic

Model comparison – thoughts

- Differences between models come from:
  - Water level alignment not being precise
  - Resolution of underlying data
  - Source of underlying data
  - Model parameters?
    - For example: InVEST includes marsh accretion that might contribute to longevity of tidal swamp, but evidence is unclear since SLAMM also includes accretion and shows tidal swamp drowning at 2 ft water level
- There are not strong patterns between marsh model parameters and migration results
- Results are not consistent across locations
- Precision vs accuracy

Questions?

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