Assessing 2035 Climate Change Risk to the Chesapeake TMDL using a next-generation unstructured-grid model

Task I: Model Implementation, verification
Water quality processes

VIMS team: Joseph Zhang, Jian Shen, Harry Wang, Marjy Friedrichs, Zhengui Wang, Qubin Qin, Jiabi Du, Pierre St-Laurent
CBPO: Nicole Cai
UMCES team: Jeremy Testa

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VIMS | William & Mary
Virginia Institute of Marine Science

SCHISM

Outline

- Proposed MBM Water quality model (ICM) update
- Approaches and decisions
- Future improvements

MBM framework

SCHISM ICM update

- Integrate the latest ICM changes into MBM
- Update mode to meet the needs of MBM
- *ICM code development*

ICM model update

State variables
Biochemical processes
Living resources
implementation & degree of complexity

Shallow water capability

Benthic algae
Marsh plant

Climate change implementation

P-T curve
Boundary condition

Enhancement of model capability to improve model performance (water quality)

MBM: State variables to be simulated

- Algae (three assemblages)
- Carbon (RPC, LPC, DOC)
- Nitrogen (RPN, LPN, DON, NH4, NO23)
- Phosphorus (RPP, LPP, DOP, PO4: partition to dissolved and particulate)
- Silicate (particulate biogenic silica, dissolved silica)
  - P is the primary limiting nutrient in spring.
- Do we need to add a slow reactive DOC to account for watershed input?
- Use net settling for particulates?

- Add slow refectory variables for C, N, P, which will be routed directly to G1,G2, and G3 in the bottom sediment model. It is convenient to handle shoreline erosion
- Simulate particulate IP and dissolved IP separately instead of using partition of total IP. The approach will be easy to handle particulate IP simulation and reduce the uncertainty of estimating partition coefficient. No settling of DIP during transport
- Use net settling for particulates and allow modification of settling velocity of the bottom water column layer to account for resuspension effect
- Silicate will not be simulated
- Slow reactive DOC will not be considered

State variables to be simulated

- Current SCHISM model uses particulate organic carbon as a surrogate for particulates (light function, phosphate sorption)
- Do we need to simulate inorganic sediment (it is also related to light)?

- We will simulate inorganic suspended sediment (ISS)
- We will simulate three classes of sediment: clay, silt, and sand
- Wave and current interaction will be considered.
- Wave will be simulated by the hydrodynamic model
- Bottom sediment deposition only includes one layer instead of simulating multiple deposition layers.
- We are evaluating two approaches (efficiency is the main consideration)
  - Simulate ISS in hydrodynamic model and pass sediment to ICM
  - Simulate wave-current interaction in hydrodynamic model and pass shear stress to the ICM. ICM will simulate suspension, settling, and ISS transport

State variables to be simulated

- *Zooplankton will not be simulated for model calibration*
- Benthic algae will be simulated in shallow water
- Living resources (oyster, clam etc.) will be simulated
- *Add ICM code (oyster, clam etc.) to MBM*
- *Use ICM oyster location and biomass to setup MBM*

Wetland: using removal rates and area to determine nutrient removal

- Simplified approach will be used by MBM
- The effect of nutrient and DO removal by wetlands will be simulated by the current ICM approach
- Full marsh plant simulation module will be included in the ICM for the applications for tributary model

Wetland: using removal rates and area to determine nutrient removal

- DO respiration

Net DO uptake is represented in equation 3:

$$V \cdot \frac{dDO}{dT} = Transport + Kinetics - f(DO) \cdot f(T) \cdot WOC \cdot Aw$$

where:

DO = DO concentration (g m^{-3})
$f(DO)$ = limiting factor: DO/(Kh + DO)
Kh = DO concentration at which uptake is halved (g m^{-3})
WOC = wetlands oxygen consumption (g m^{-2} d^{-1})

If oxygen consumption is reduced by oxygen availability in the water column, chemical oxygen demand equivalent to the reduction is released from the wetlands so the total respiration, in oxygen equivalents, is constant.

Wetland

- Removal of nutrients and DO consumption have been observed and the rate used by ICM will be used for MBM

Table 4-2. Summary of Wetlands Process Observations Used in Parameterizing and Validating the Module

CBPS	C Deposition ($g\ m^{-2}\ d^{-1}$)	N Deposition, ($g\ m^{-2}\ d^{-1}$)	P Deposition, ($g\ m^{-2}\ d^{-1}$)	Denitrification ($g\ N\ m^{-2}\ d^{-1}$)	Solids Deposition ($g\ m^{-2}\ d^{-1}$)	Respiration ($g\ DO\ m^{-2}\ d^{-1}$)
BSHOH		0.008 to 0.032	0.001 to 0.006			
CHOMH		0.053 to 0.074	4.9 e-4 to 0.005			
CHSMH		0.02 to 0.064	0.01 to 0.019		3.6	
FSBMH	0.39 to 0.82				0.3	
MPNOH	0.42 to 0.93	0.034 to 0.082	0.006 to 0.026		2.8 to 14.2	
NANMH	0.22 to 0.43				1.61 to 8.12	
NANOH	0.22 to 0.43				1.61 to 8.12	
PAXOH		0.037	0.006		3.8	
PAXTF		0.037 to 0.064	0.006 to 0.01	0.054 to 0.098	3.8	
PMKOH	1.42	0.05		0.023		1.12 to 2.77
POTTF	1.27			0.043 to 0.06	6.35	
WICMH	0.22 to 0.43	0.037	2.74 e-5 to 0.004		1.61 to 8.12	

Notes: C = carbon; CBPS = Chesapeake Bay Program Segment; $g\ m^{-2}\ d^{-1}$ = grams per square meter per day; N = nitrogen; P = phosphorus.

Cerco & Noel, 2019

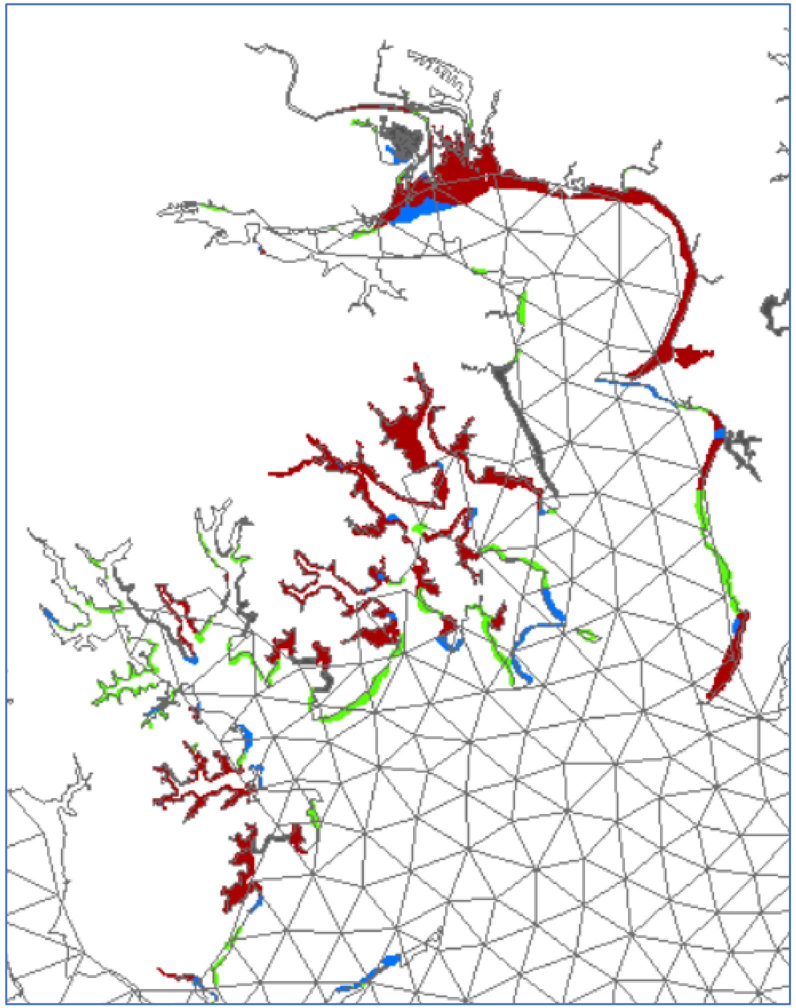
SAV simulation

- Mode grid size may not match to SAV area
- Consider determining SAV area for each grid element
- Two approaches for SAV initialization

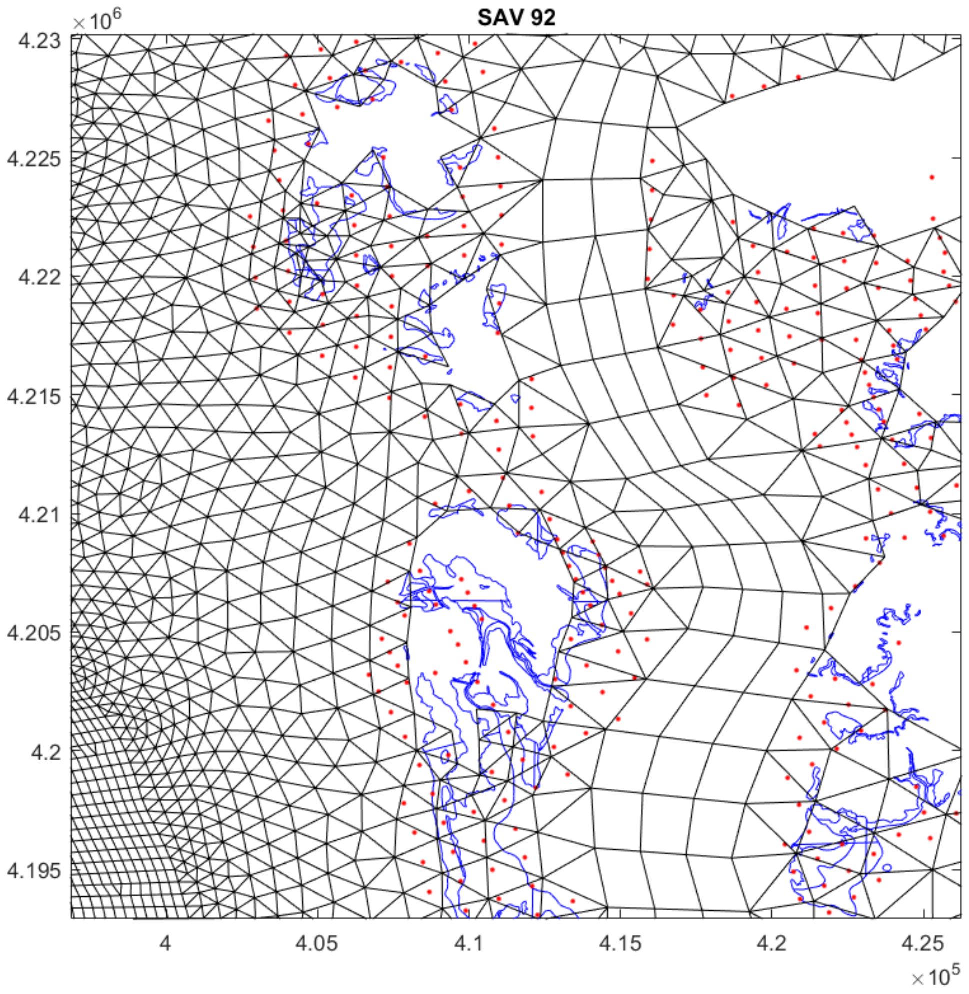
(1). Use ICM approach and set SAV seeding areas in shallow area. SAV growth depends on nutrients and light

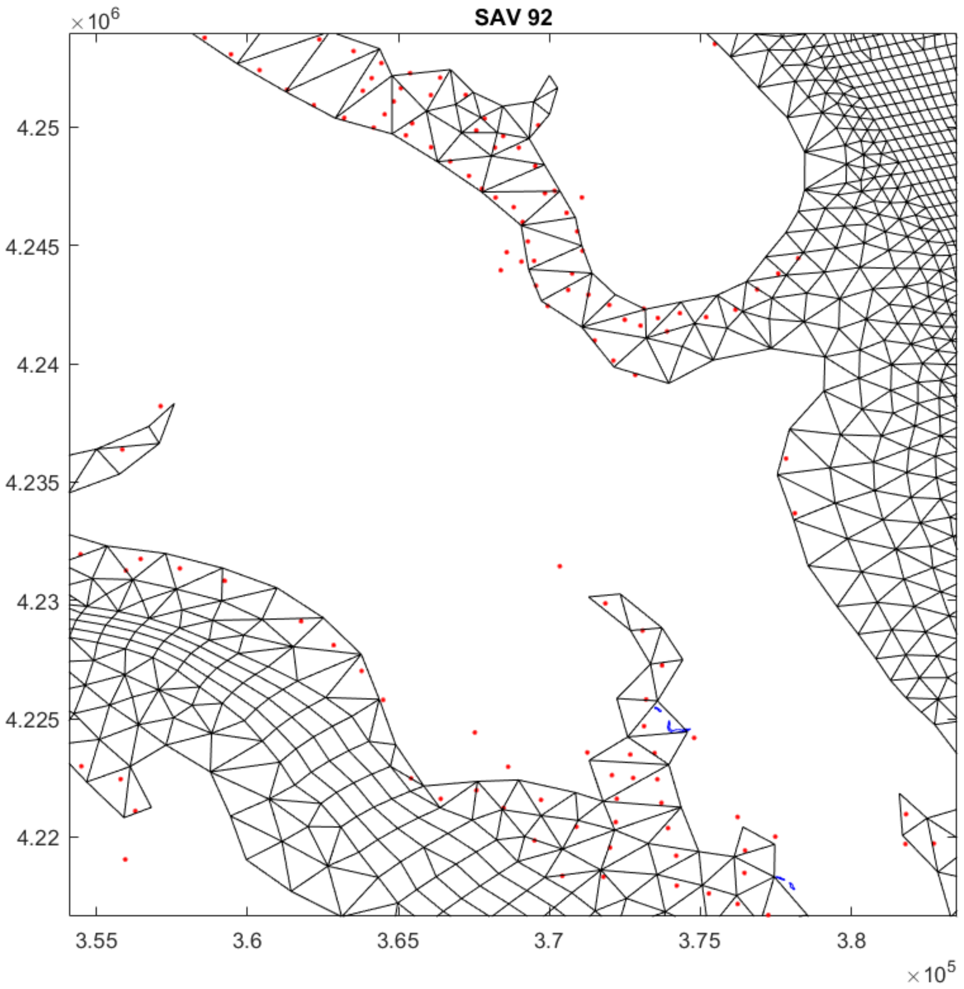
(2). Use VIMS survey data to set SAV seeding areas, Input area for each year as re-initialization (area correction)

2010 SAV distribution



SAV simulation



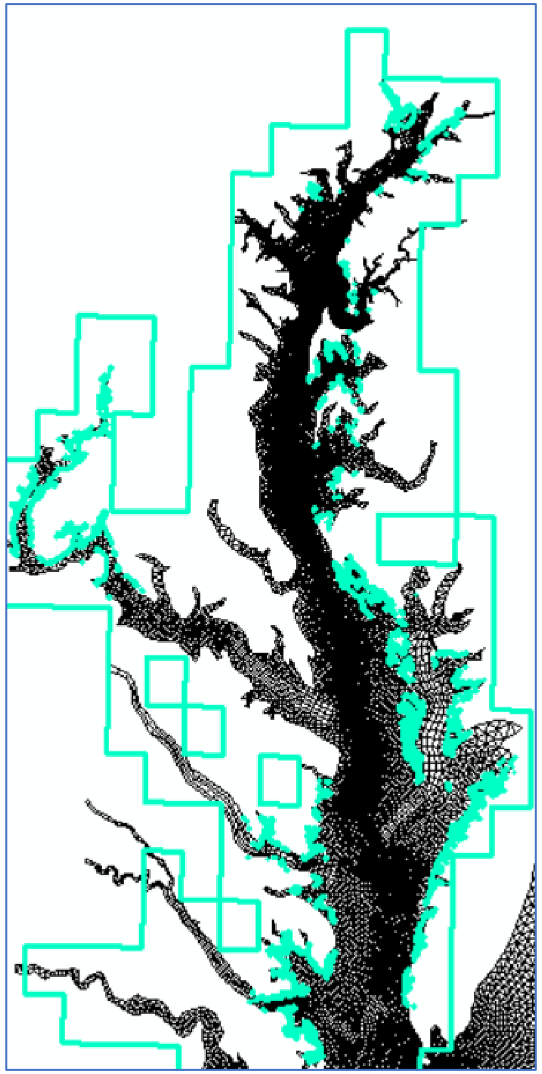


Blue lines are SAV survey coverage. Red dots are center of ICM grid with SAV

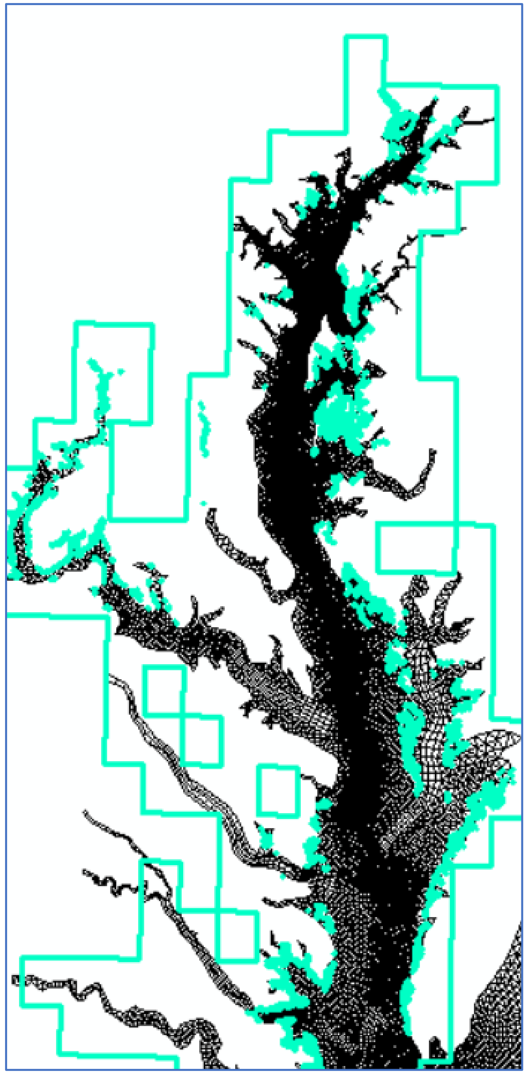
Proposed SAV simulation

- Use VIMS survey data to set SAV seeding areas, Input area for each year as re-initialization (area correction)

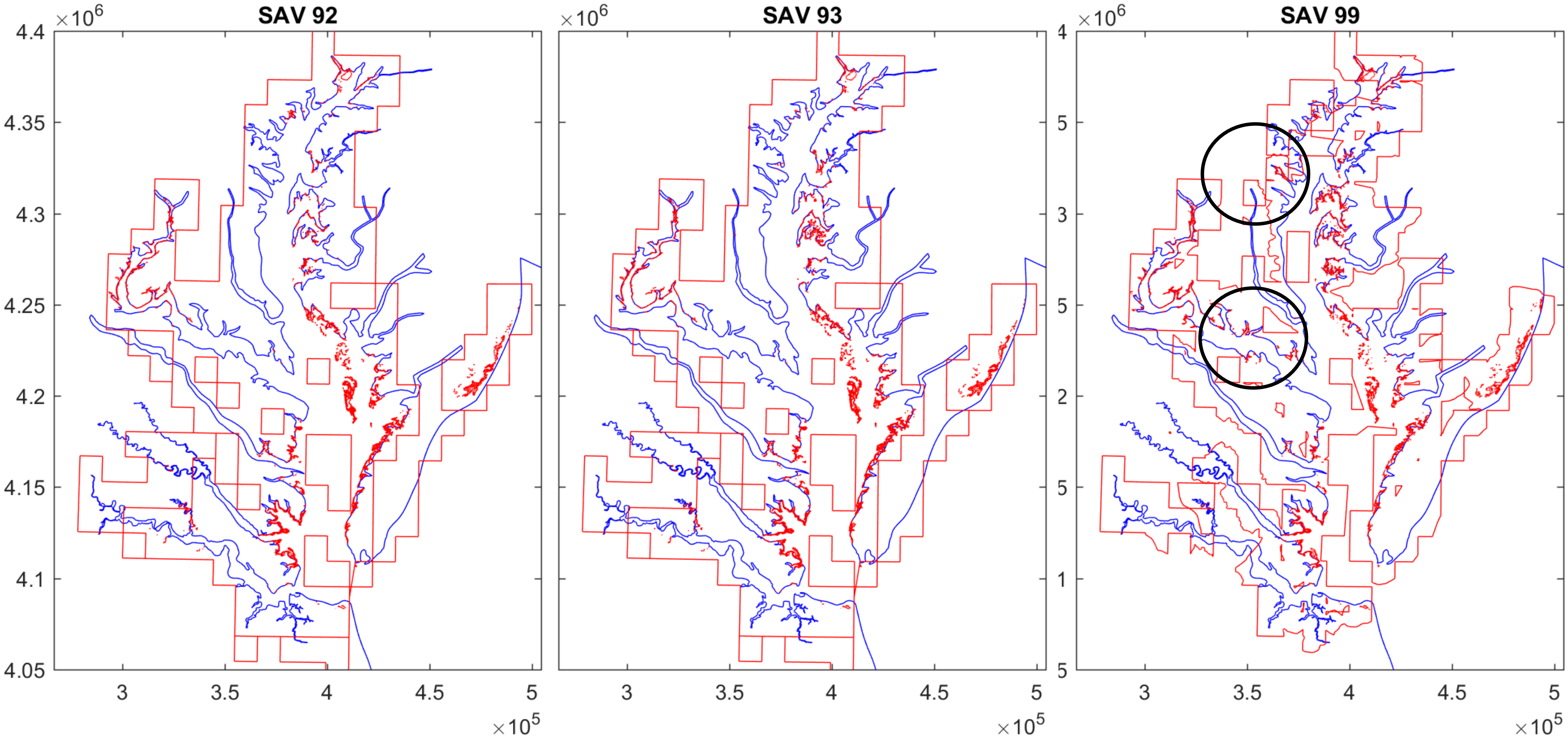
1990



1994



Variation of SAV



Climate Change Consideration

- Use different parameters for model calibration (without/with temperature inhibition)

Table 1
Revised Algal Parameters for Climate-Change Scenarios

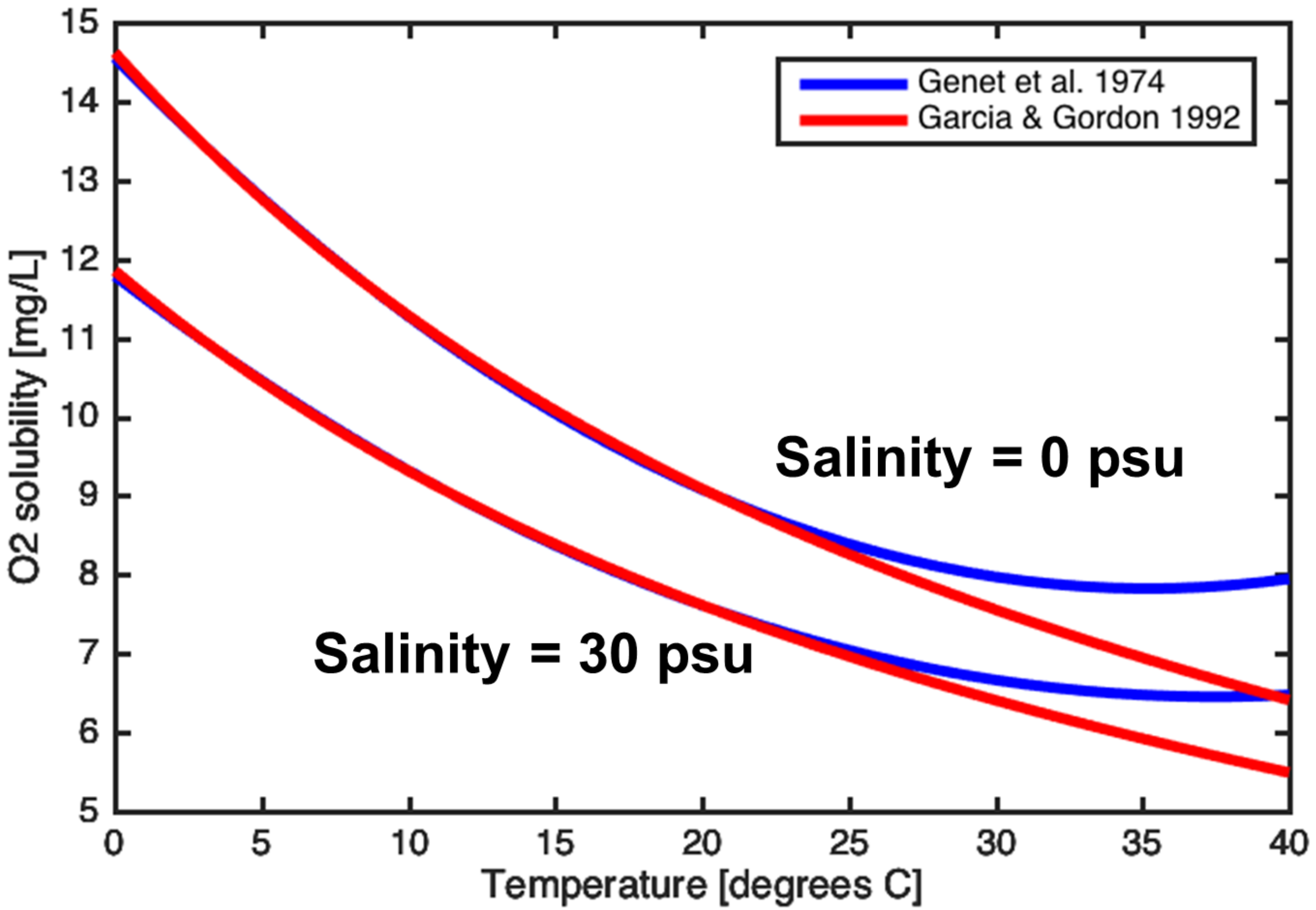
Parameter	Definition	Group 1 Calibration	Group 1 Climate Change	Group 3 Calibration	Group 3 Climate Change
KTg1	effect of temperature below Topt on algal production ($^oC^{-2}$)	0.005	0.0022	0.0035	0.0013
KTg2	effect of temperature above Topt on algal production ($^oC^{-2}$)	0.004	0	0	0
Pm^B	maximum photosynthetic rate (g C g^{-1} Chl d^{-1})	200	250	450	600
Topt	optimal temperature for algal production (^oC)	29	37	25	37

Courtesy of Cerco

Climate Change Consideration

It is noted that there are discrepancy to compute DO saturation based on different curve.

It is more reasonable to use Garcia & Gordon's 1992 curve



Courtesy of Marjy

Boundary condition for climate change

- Wetland boundary condition
  - Determine wetland boundary and inundation in new model grid
  - Need GIS layer for the new boundary
- Ocean nutrient open boundary for climate change simulations
  - Collect available nutrient data in the coast
  - Analyze data and determine the range
  - Conduct sensitivity tests to determine appropriate ways to set open boundary condition

Dissection