Simulation of SAV in the Phase 7 Main Bay Model (MBM)

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Acknowledgement

- During the last quarter, we worked closely with Gopal and Richard on testing the watershed/airshed loadings, as well as updating our MBM workflow to incorporate the new nutrient loading. The new model results are promising, and we greatly appreciate Gopal and Richard's support.

- Additionally, the VIMS team collaborated with Lew, Carl, Richard, and Gopal to fine-tune the MBM. They provided valuable comments and feedback on the MBM results, and identified several issues. We are addressing those issues and anticipate a 'baseline' version of MBM by the next quarterly.

Watershed/Airshed Loading

- With the help of Gopal and Richard, we converted the format of watershed/airshed nutrient loadings to NetCDF. All the data is included in just one file. This greatly simplifies the MBM workflow, and streamlines the coupling between WSM and MBM. Additionally, the database format allows us to efficiently perform different operations (nutrient analysis, search, mapping, etc.)

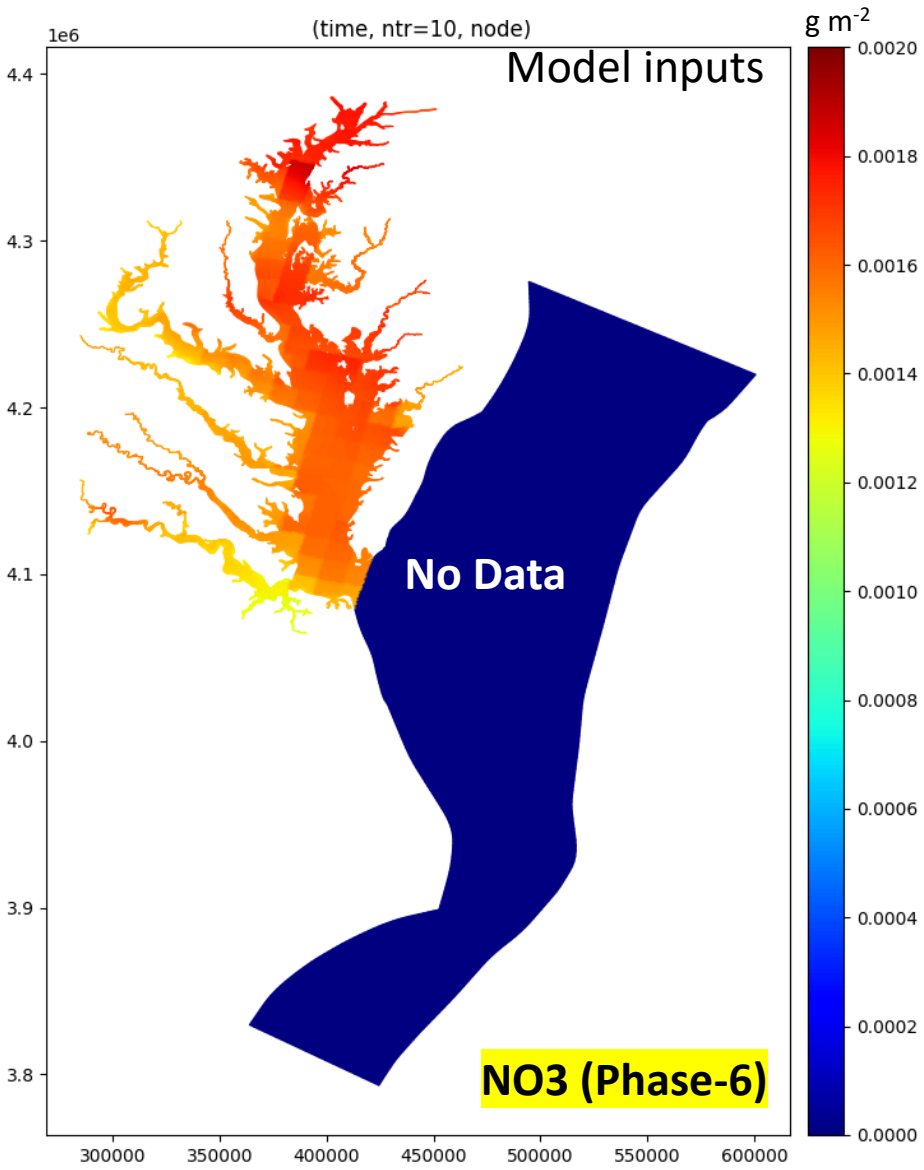
- Gopal also provided us the new P7 atmospheric nutrient deposition data. We has successfully integrated it into our MBM workflow.

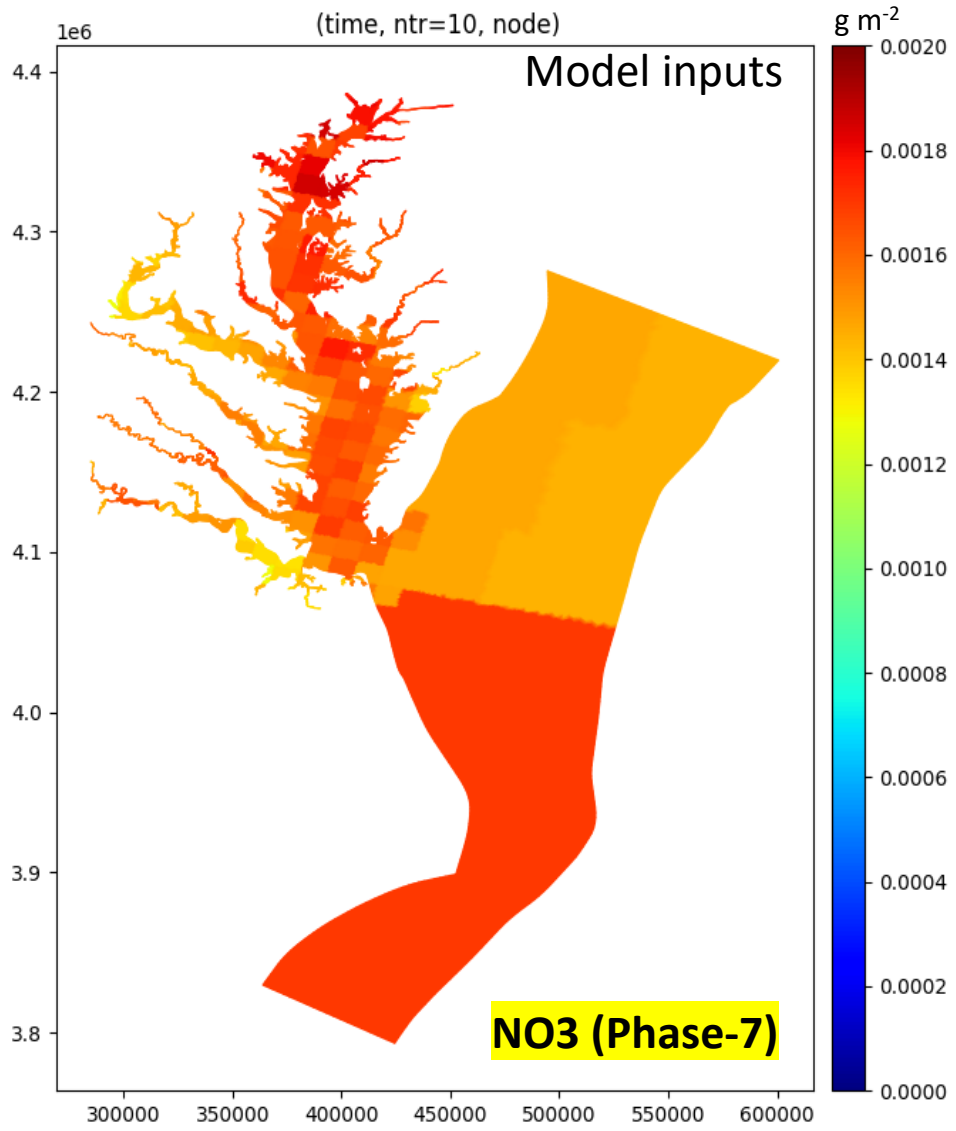
- We compared results from P7 & P6 airshed loadings. Overall, the difference seems minor.

- We worked with Gopal and tested different beta versions of P7 watershed loadings. The new results with some beta versions look promising.

Comparison of Airshed Loadings between P6 and P7

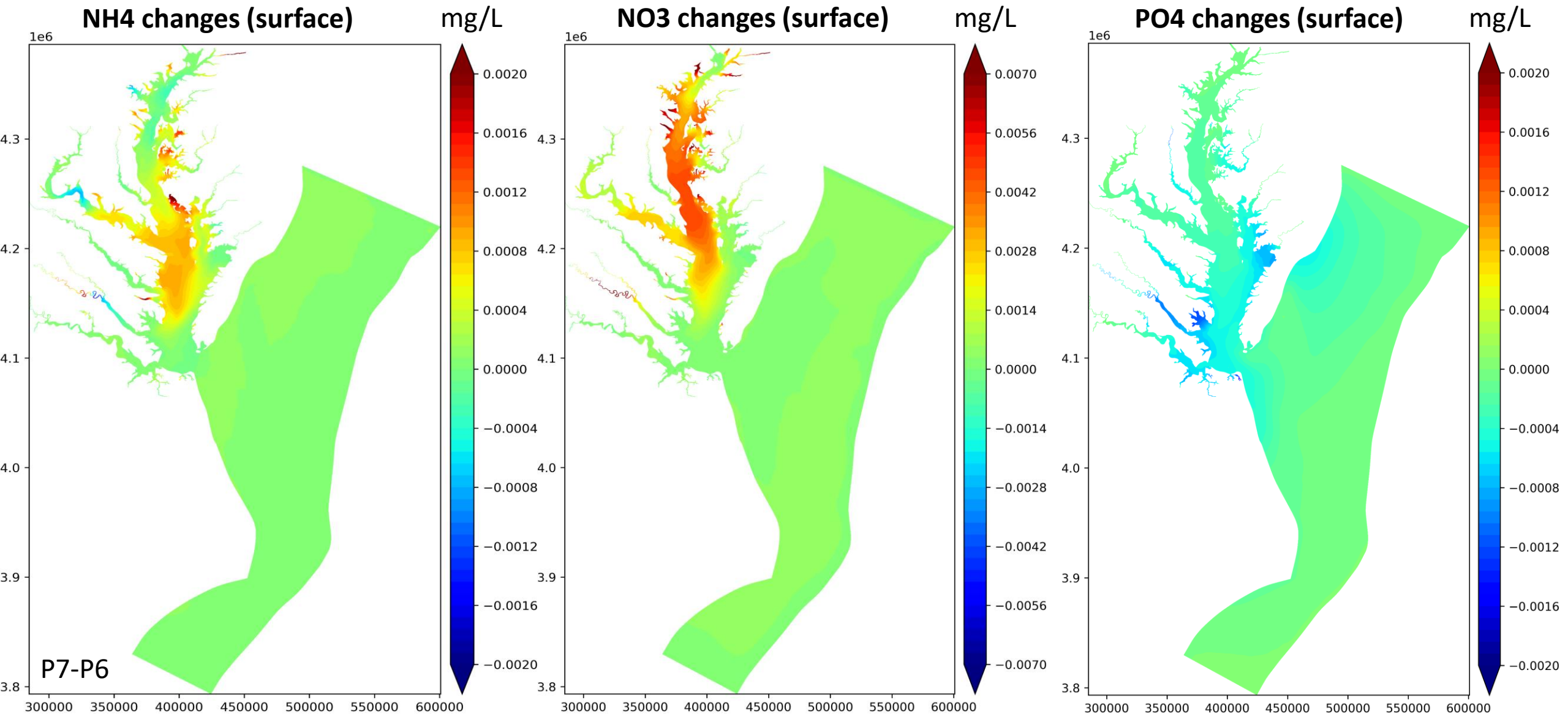
- Atmospheric loading includes N/P species
- Nutrient loading in the coastal ocean is also available in P7





Atmospheric Loading: impact on WQ

- Minor differences in the simulated NO3/NH4 using P6 and P7 atm loading (**long-term averaged**)



Work on SAV: Overview

- ❑ While calibrating MBM using new watershed loadings, we assessed important shallow-water processes related to SAV

- ❑SAV coverage and representation In MBM

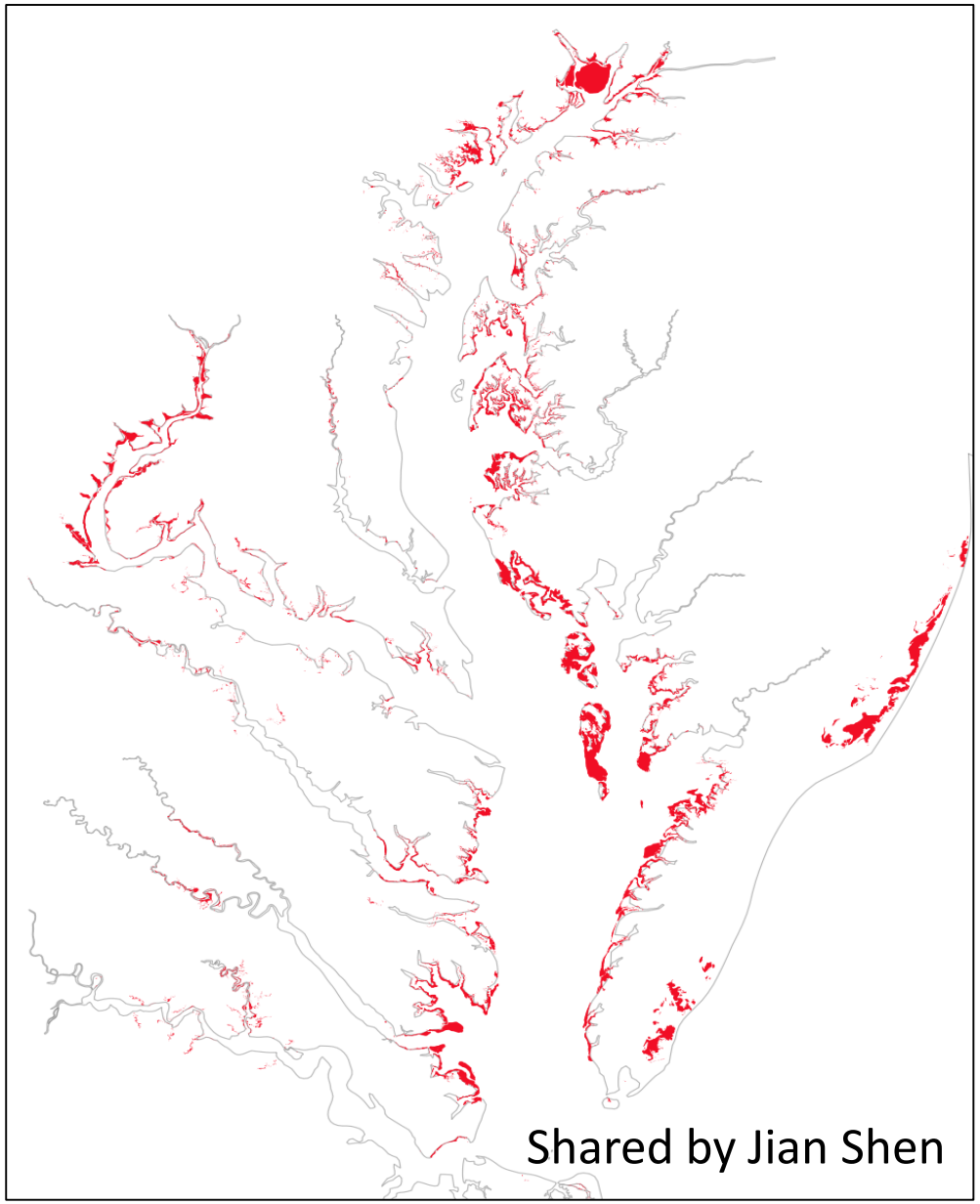
- ❑ The hydrodynamic simulation of SAV effect in Chesapeake Bay
  - Model configuration
  - SAV effects on current/wave/benthic stress/TSS

- ❑ The biological simulation of SAV in ICM
  - Introduction about SAV modeling in ICM
  - SAV calibration and effects on DO
  - Earlier issues of SAV modeling and resolutions

- ❑Summary and future work

SAV Coverage in Chesapeake Bay

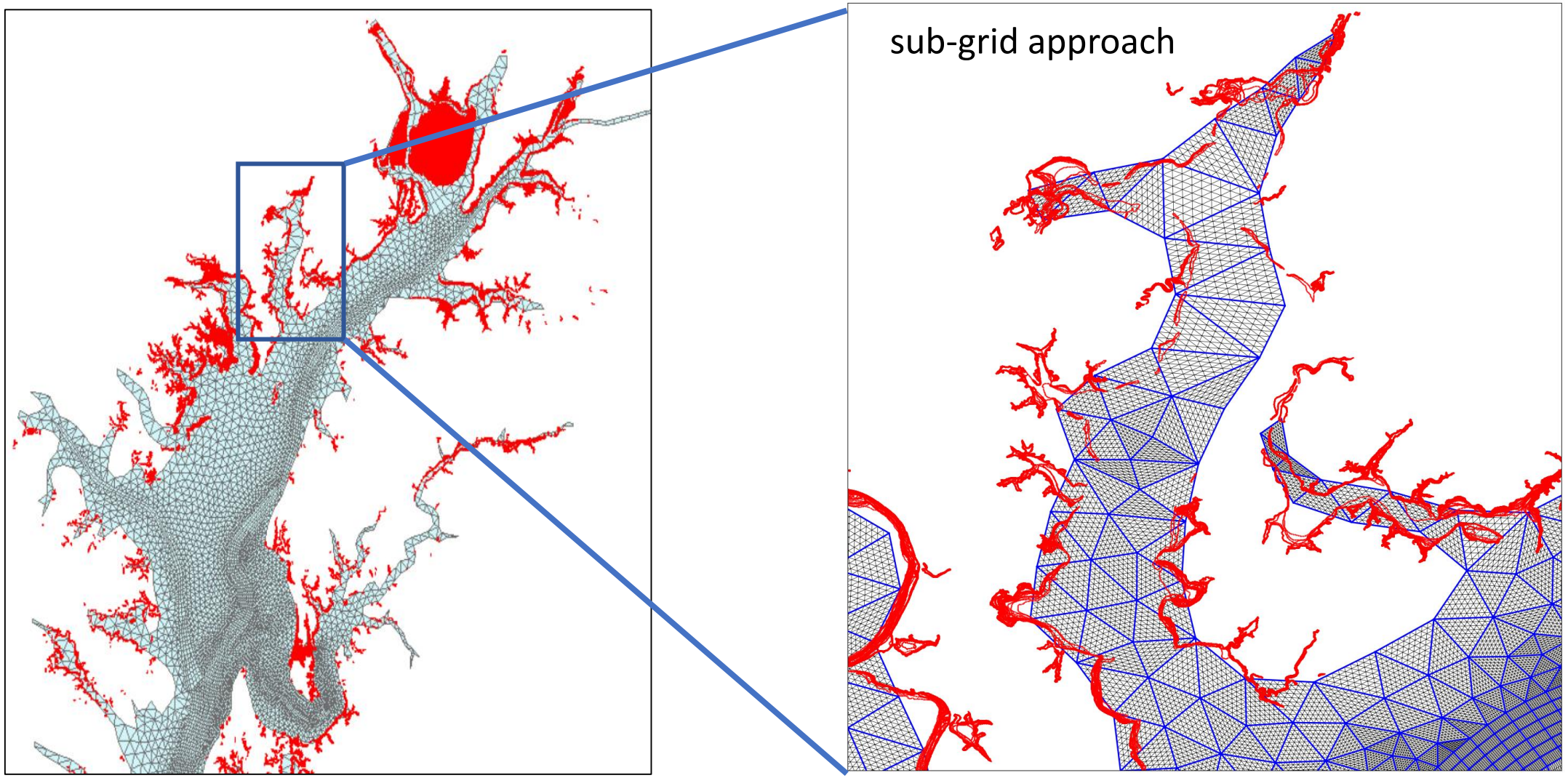
SAV coverage from 1990 to 2020



- ❑ SAV coverage data is from VIMS surveys
  - The observations of SAV biomass are very limited. Future work may infer biomass data from SAV density.
- ❑ Coverage features
  - Very patchy
  - Located in shallow regions. Often near the MBM domain boundaries
- ❑ SAV modeling
  - Hydrodynamic modeling
  - Biological Modeling ICM by Carl, Nicole, etc.
  - Although SAV Coverage data spans from 1990 to 2020, we only used the multi-year averaged SAV coverage in simulations.
  - In the future, we will simulate SAV year by year.

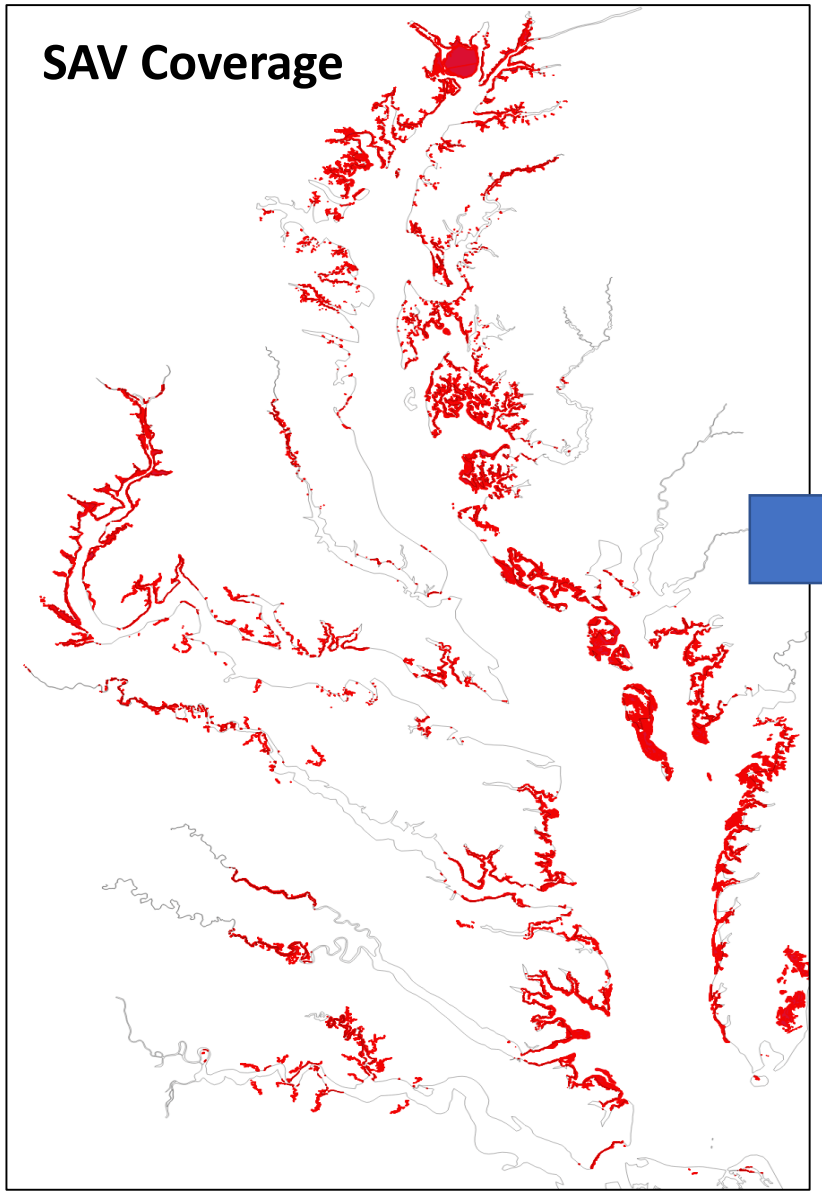
How SAV Coverage is integrated to MBM modeling grid

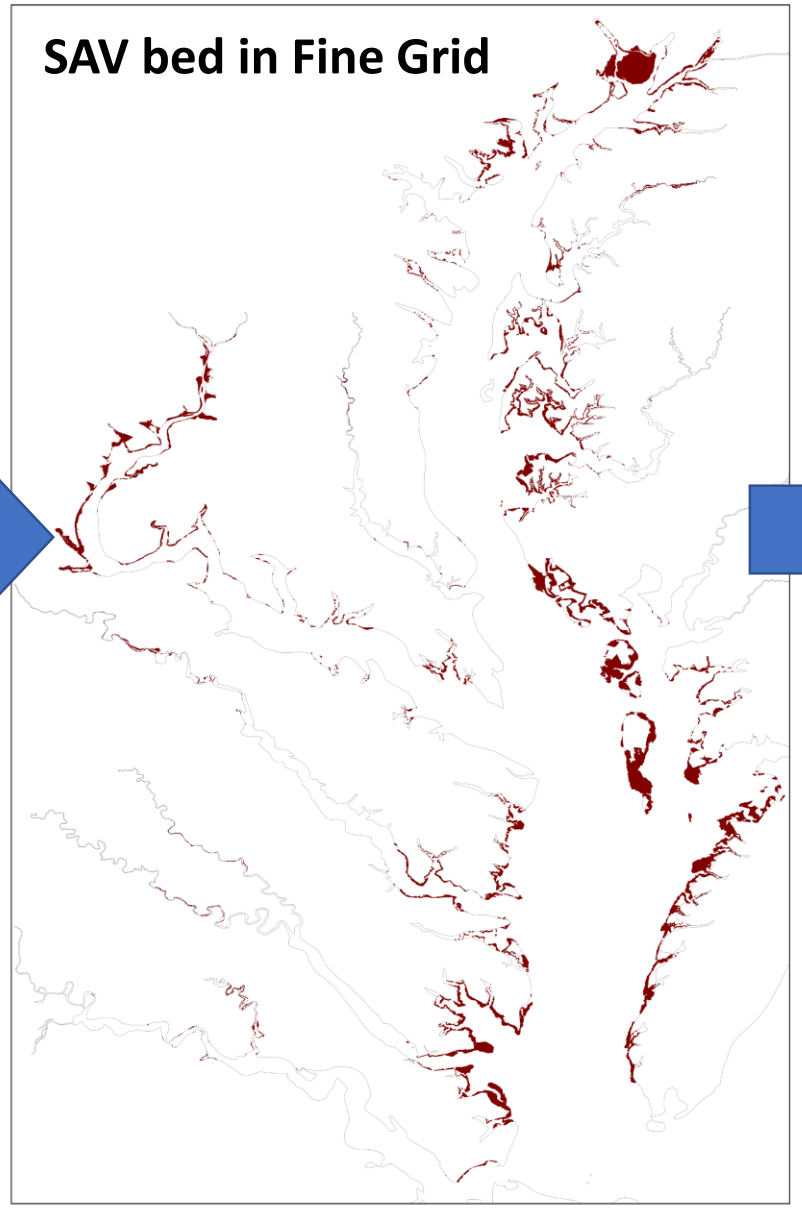
- **Challenges:** To simulate SAV, the representation of SAV bed in MBM gird is a tricky issue
- **Solution**: 1). For each MBM cell, assign a SAV coverage fraction. 2). Compute coverage fraction in sub-grid

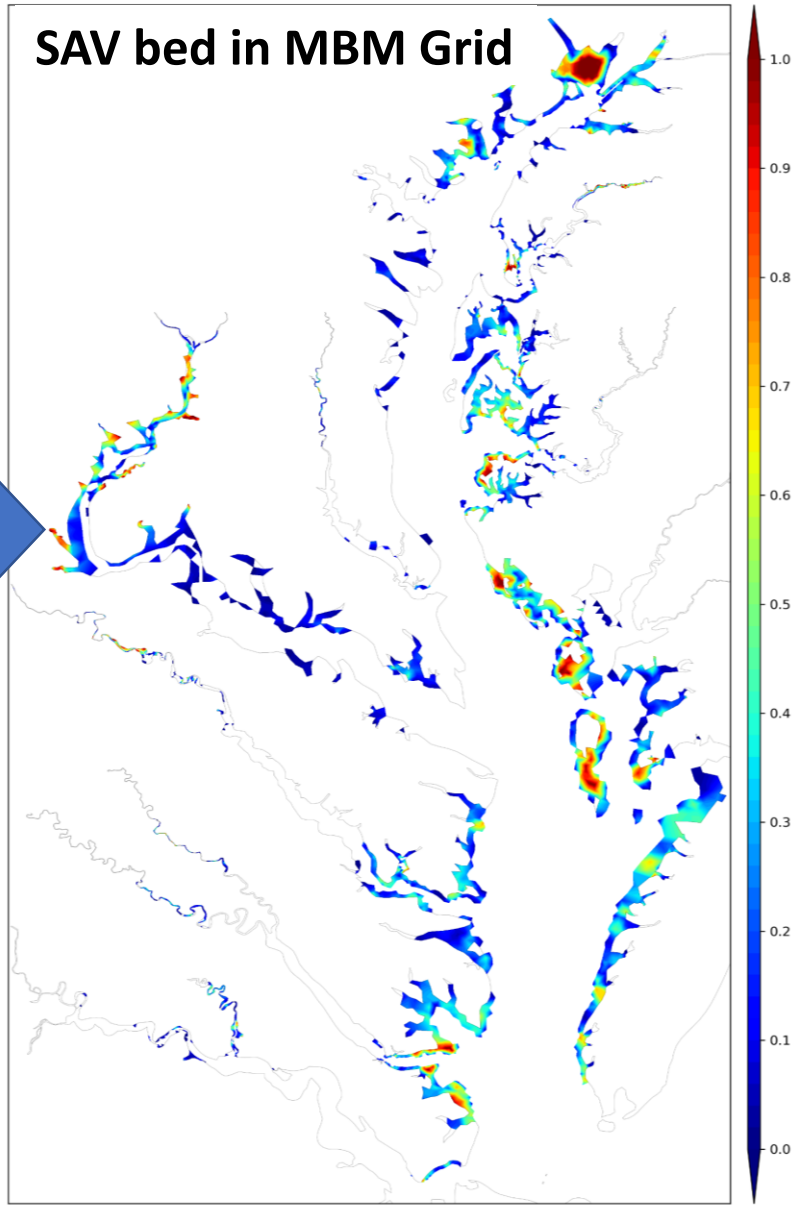


SAV representation in MBM modeling grid

❑ Overall, SAV coverage in Chesapeake Bay is well represented in MBM

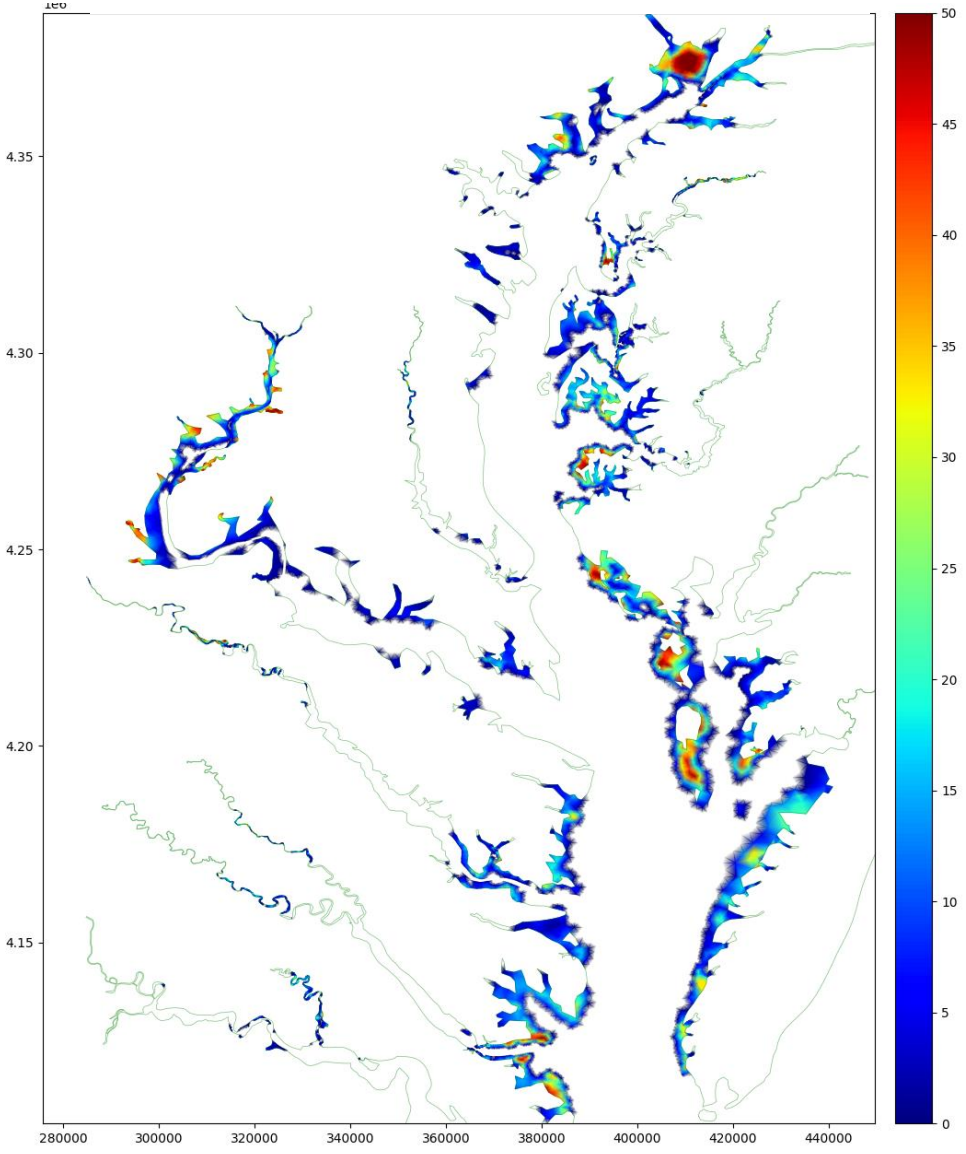






SAV configuration for the hydrodynamics in MBM

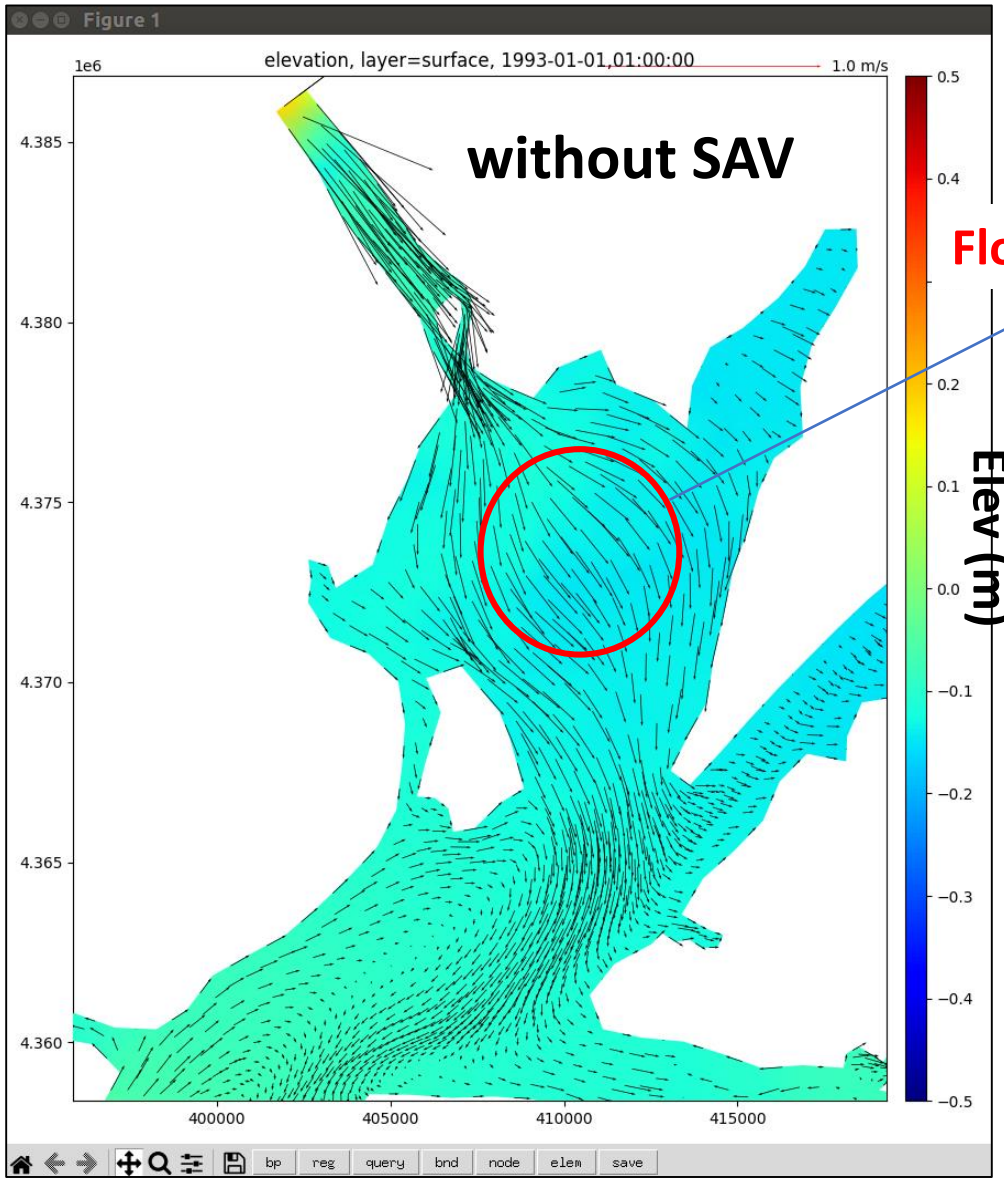
SAV density: number of stems per m^2



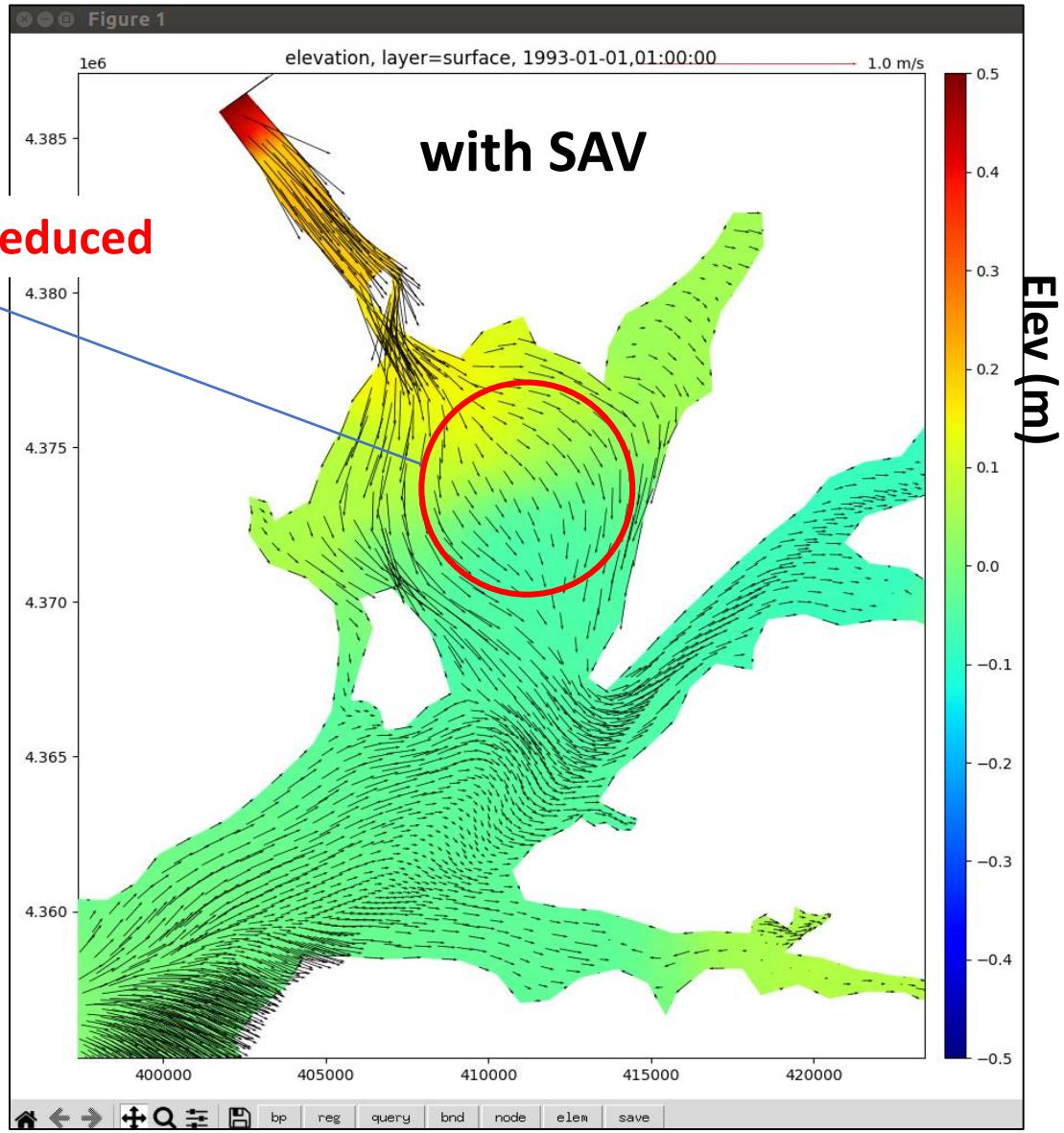
- In SCHISM model, the SAV physics are simulated in VEG module.
- This is a fully dynamic model that can simulate the interactions between SAV and current/sediment/wave.
- Inputs for SAV bed include:
  - SAV canopy height
  - SAV stem diameter
  - **SAV density (# of stems per m^2)**
  - SAV drag coefficient
- Constant values are assumed to SAV canopy height (0.5 m), stem diameter (0.01 m), and form drag coefficient (1) due to lack of obs.
- SAV fraction is converted to SAV density.

SAV Effect on the hydrodynamics

- ❑ Current speed is reduced inside SAV bed.
- ❑ Water level (color) setup due to SAV effect is obvious.



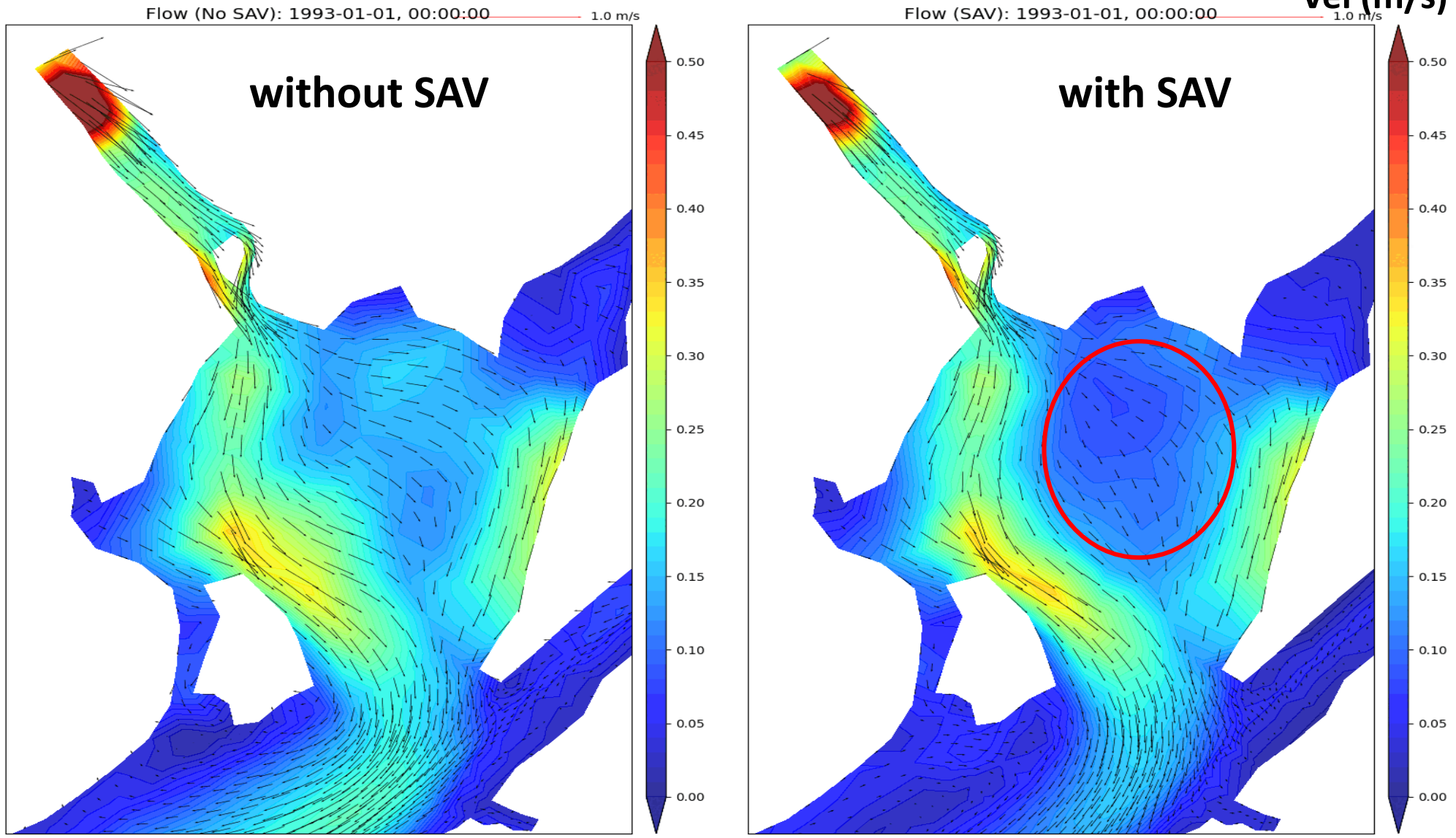
Flow is reduced



Comparison of flow field with and without SAV

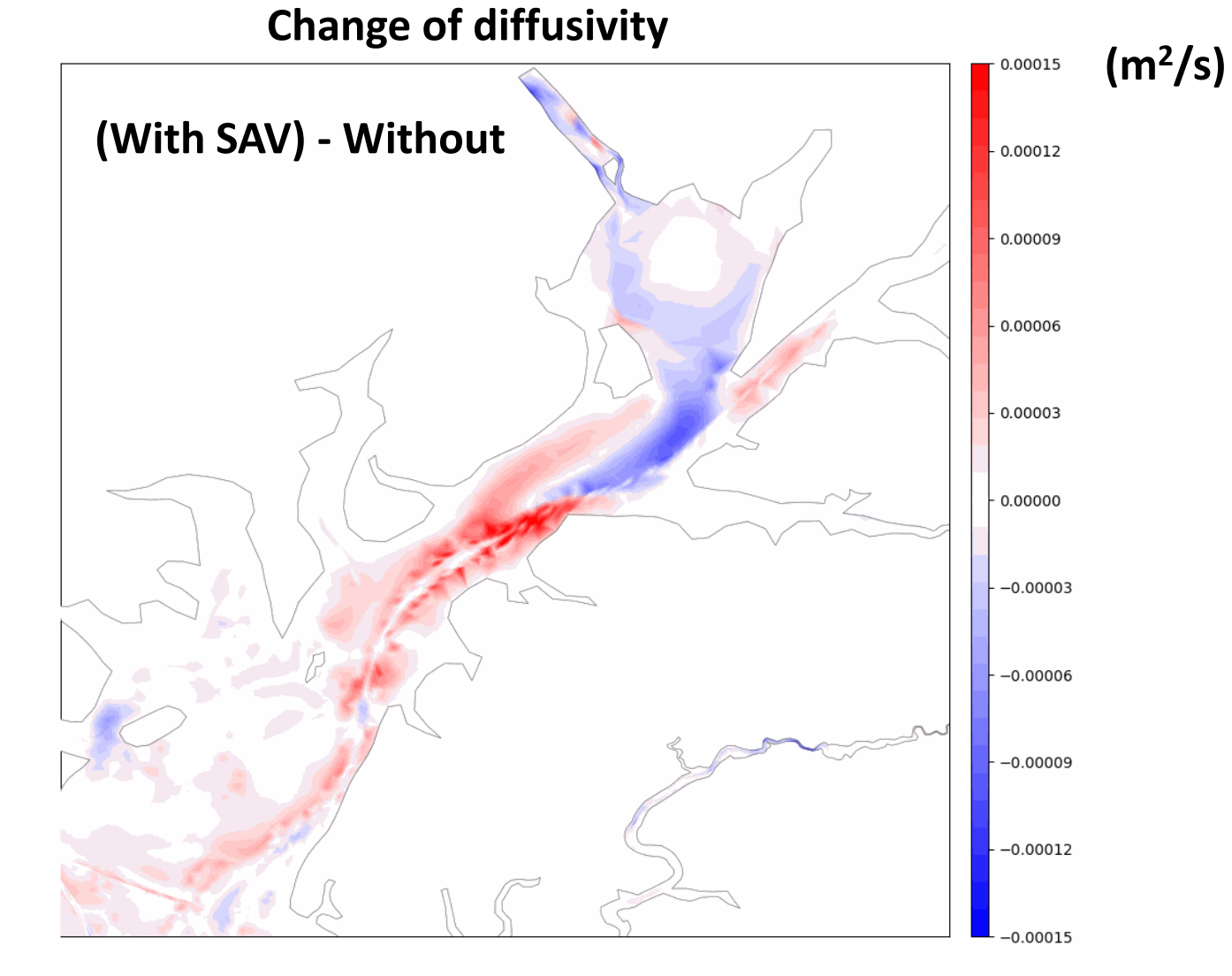
- ❑ Reduction of current speed inside SAV bed is well simulated in the MBM
- ❑ Enhanced channel flow outside SAV bed

The background color represents the surface current speed



SAV effect on diffusivity

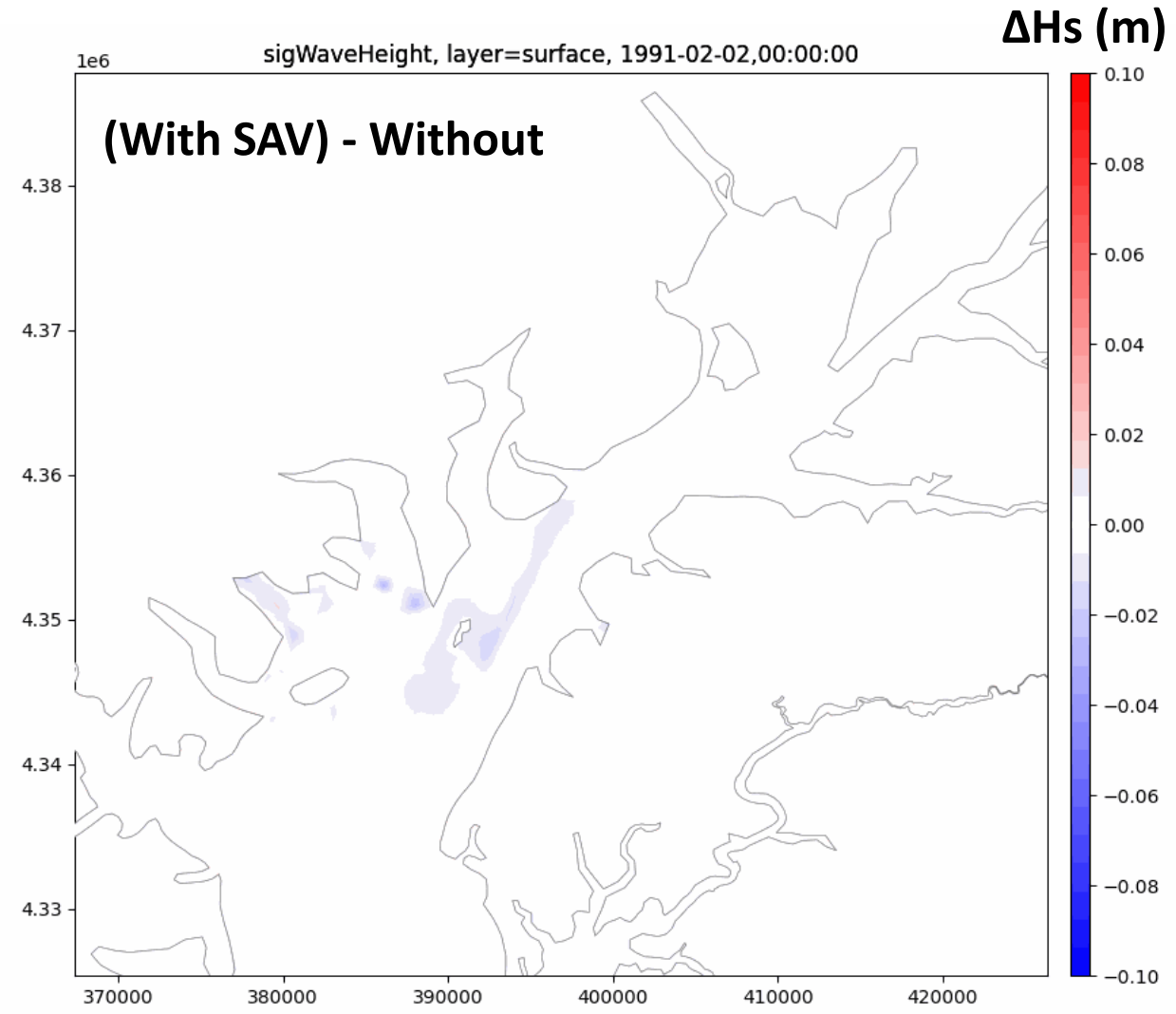
- ❑ With SAV, turbulence around the SAV bed is generally reduced
- ❑ Higher flow in channel outside the bed led to higher turbulence at times



SAV effect on wave attenuation

- ❑ SAV is coupled with wind wave model in MBM
- ❑ Wave attenuation inside SAV bed is well simulated

- ❑ Difference of significant wave height (Hs)
- ❑ As a result, turbulence and TSS are reduced

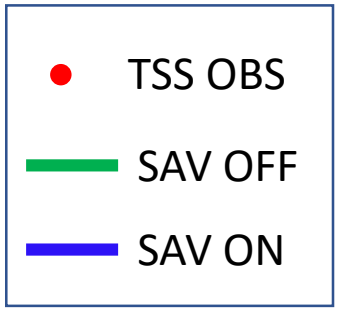


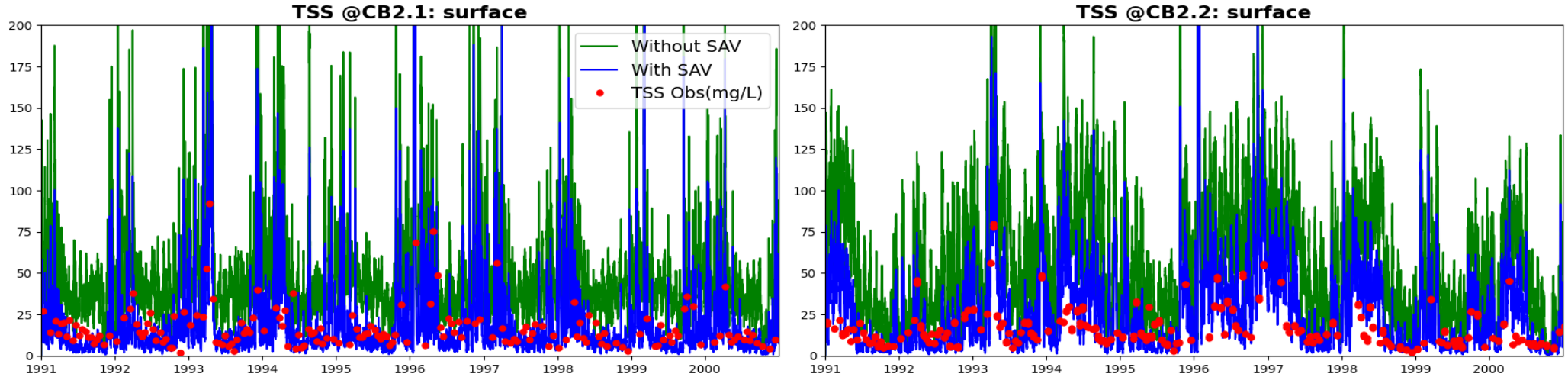
SAV Effect On The Sediment Concentration: Temporal Variation

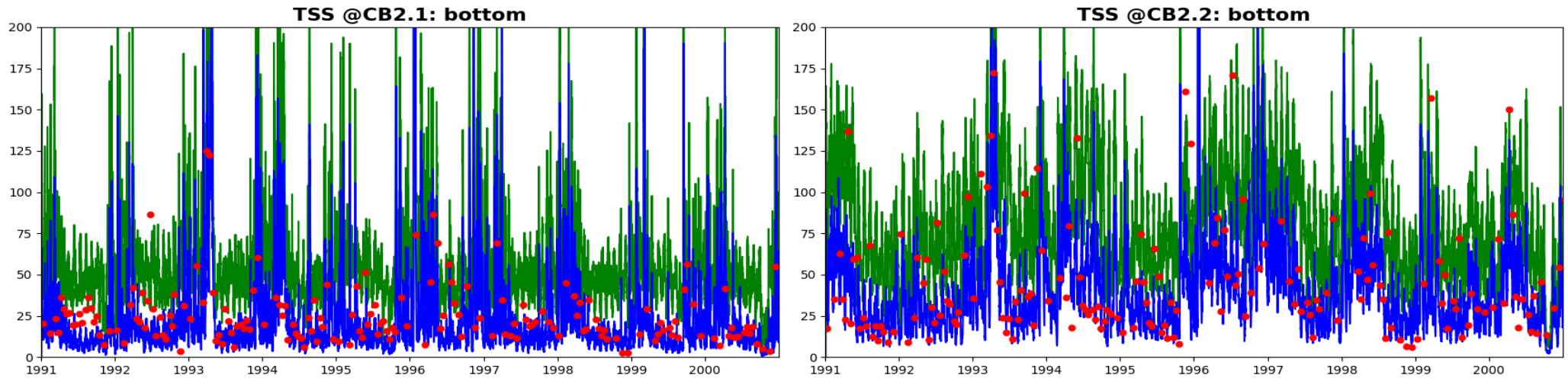
- SAV is coupled with dynamic sediment transport model in MBM.
- With SAV module, the simulated TSS is reduced and matches better with observations.
- Interaction with SAV bed also affected TSS in the downstream

Surface

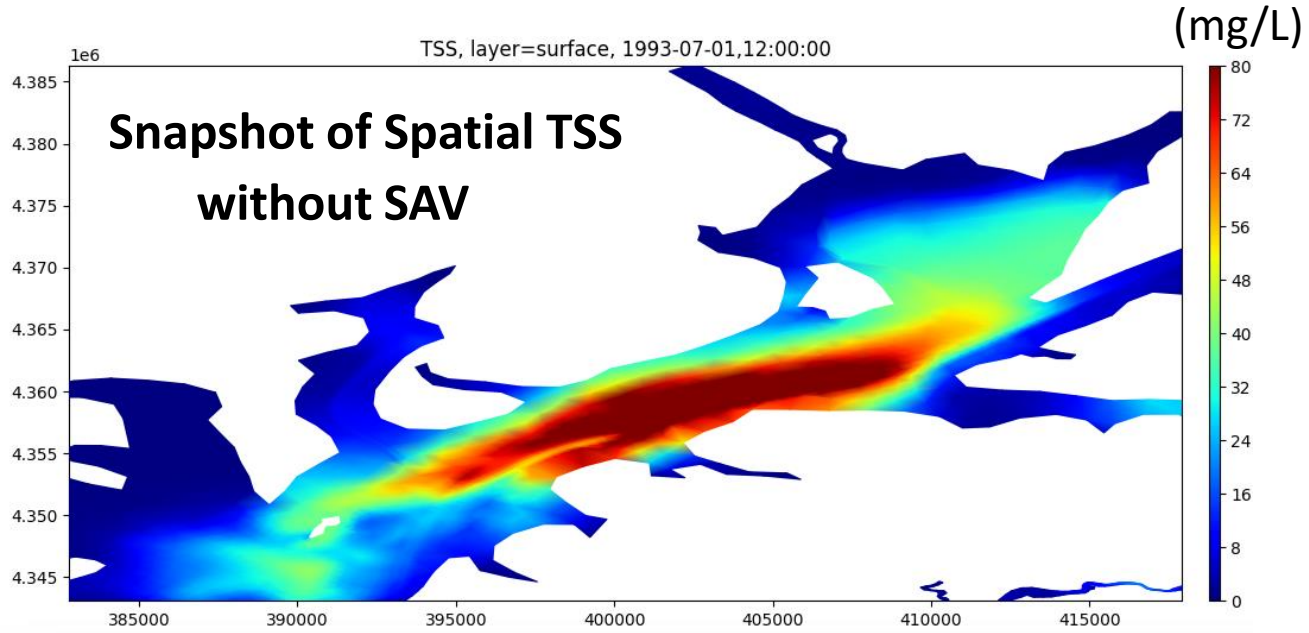
Bottom

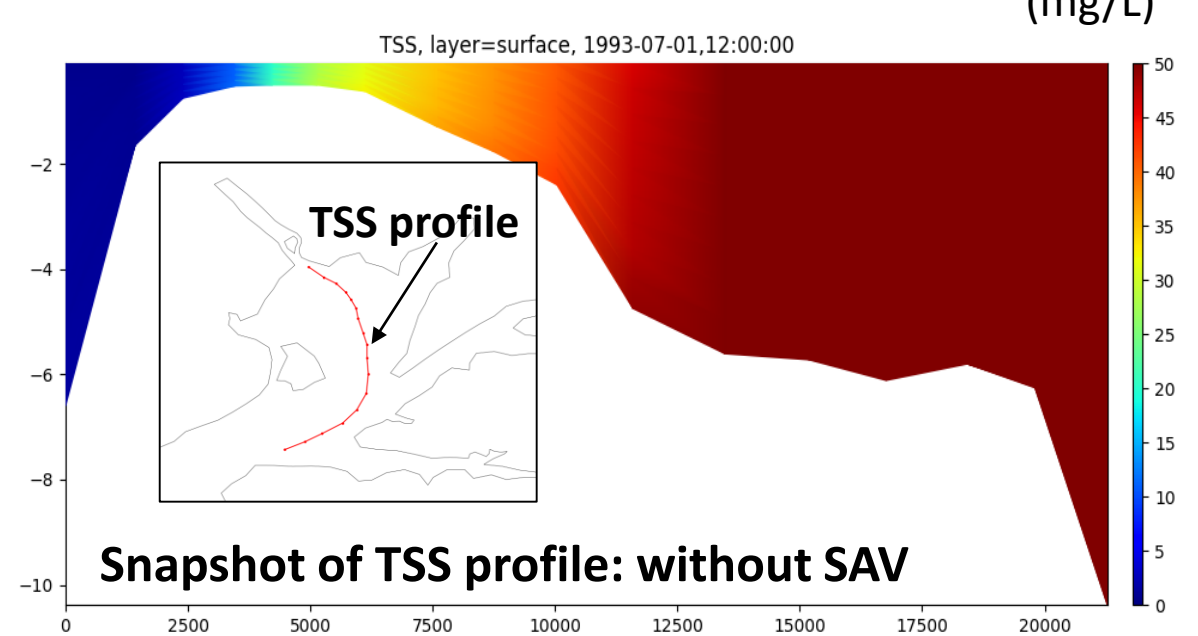


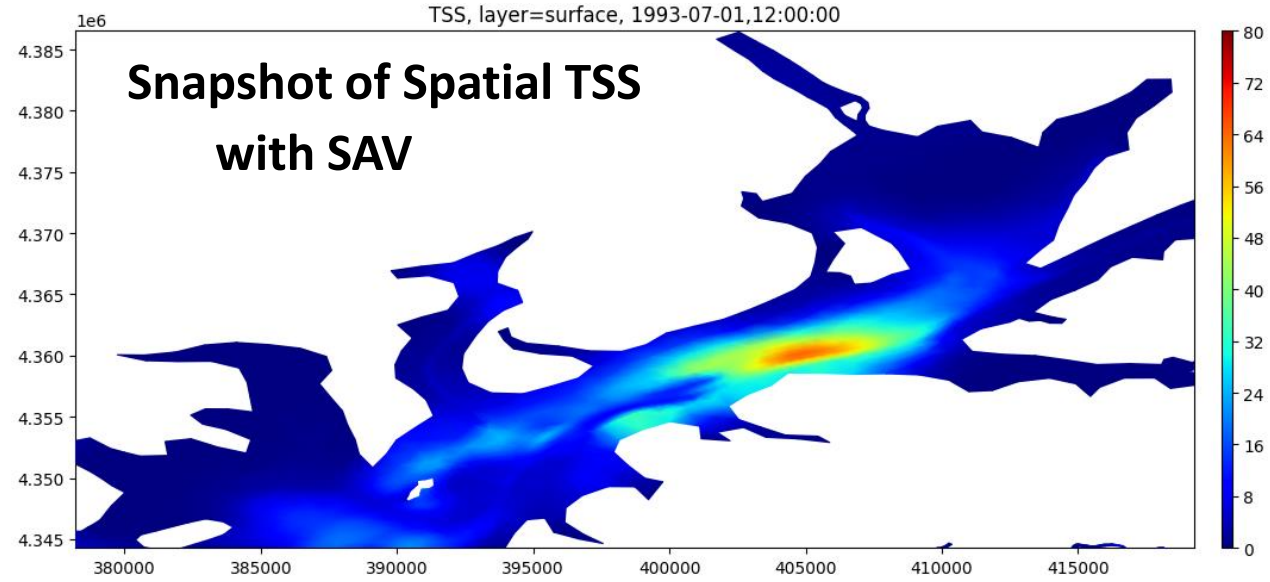


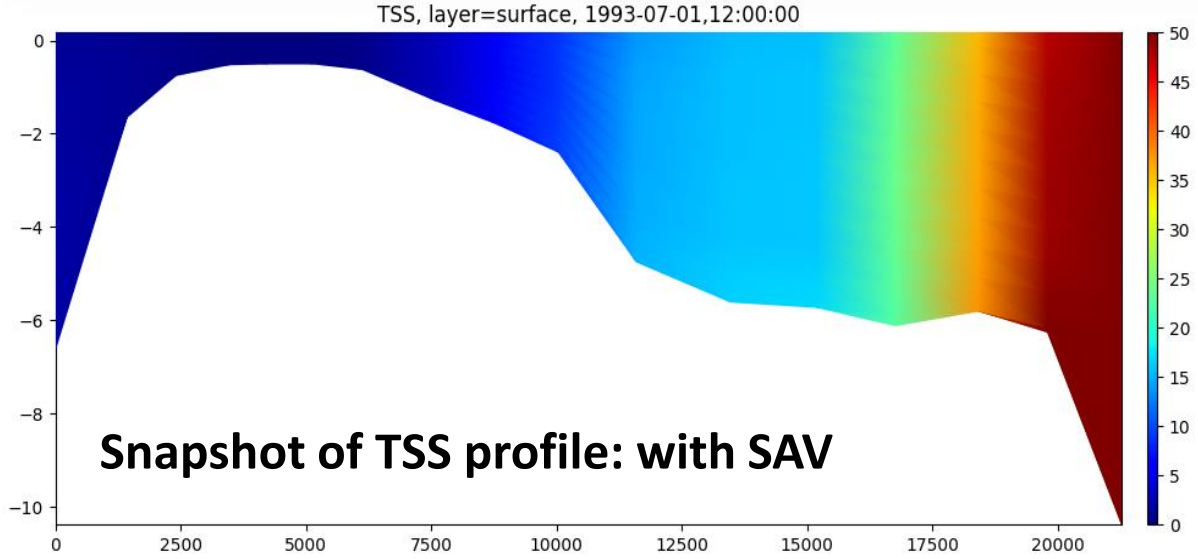


SAV Effect On The Sediment Concentration: Spatial Variation



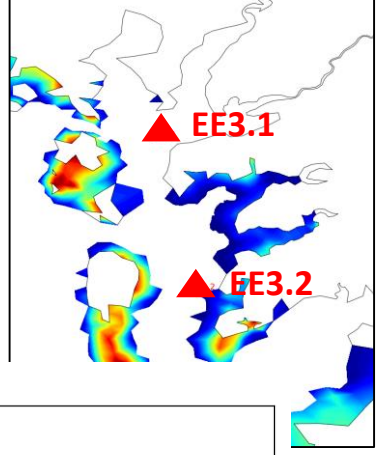






SAV Effect on the sediment concentration in other regions

- SAV effects on TSS tend to be smaller in other regions where SAV beds are smaller than Susquehanna Flat.

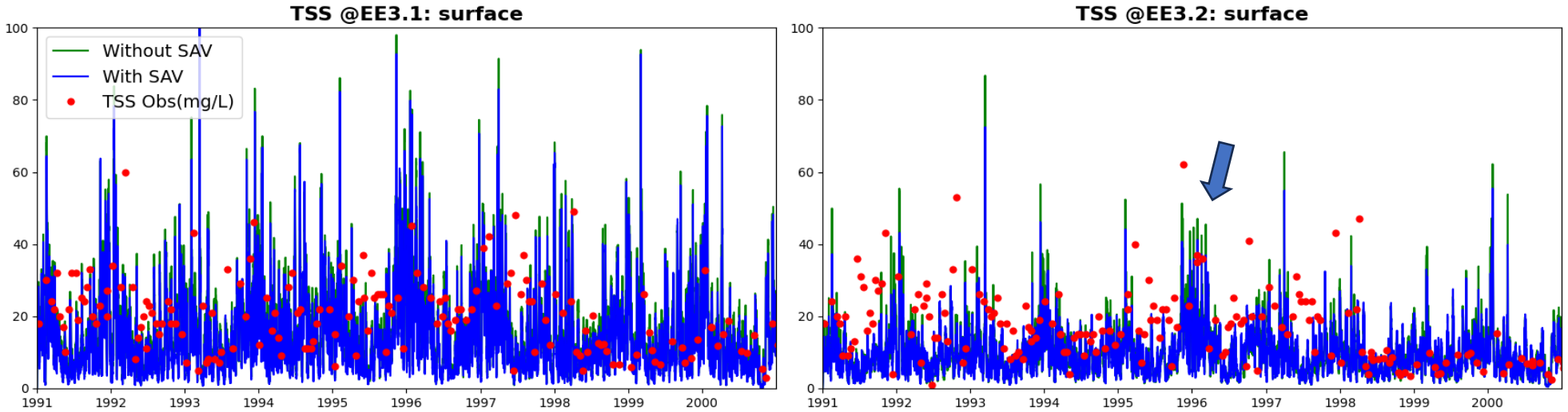


TSS OBS

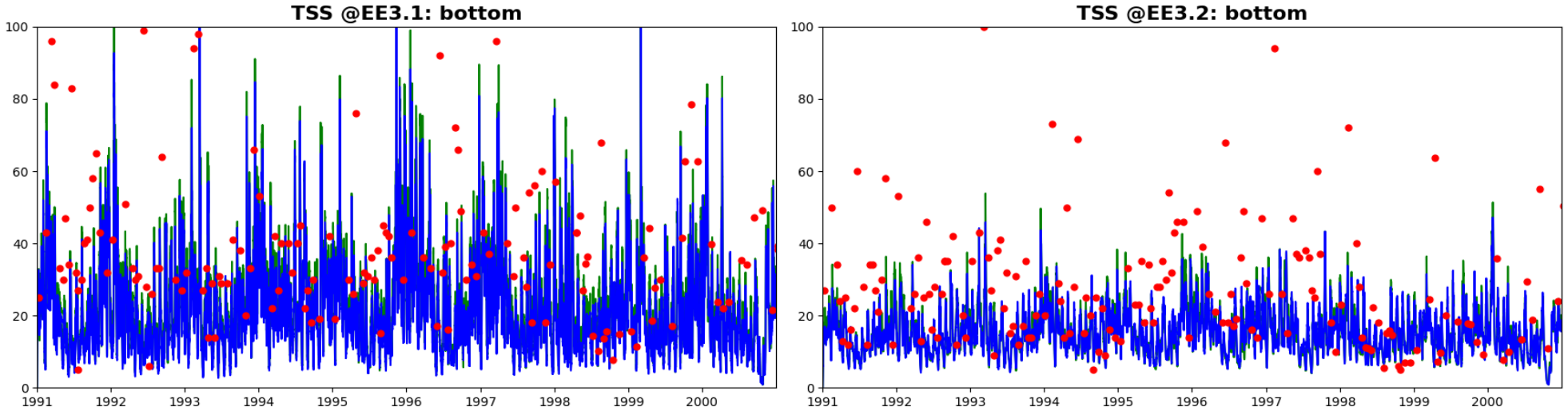
SAV OFF

SAV ON

Surface



Bottom



SAV impact on water quality

❑ The biological SAV component in MBM is a fully dynamic model

Spatial varying coverage and fraction are used for SAV bed.

❑ Major Variables In SAV Model

- SAV leaf, stem, root and tuber (g[C].m^{-2})
- SAV canopy height (m)

❑ Major Processes In SAV Model

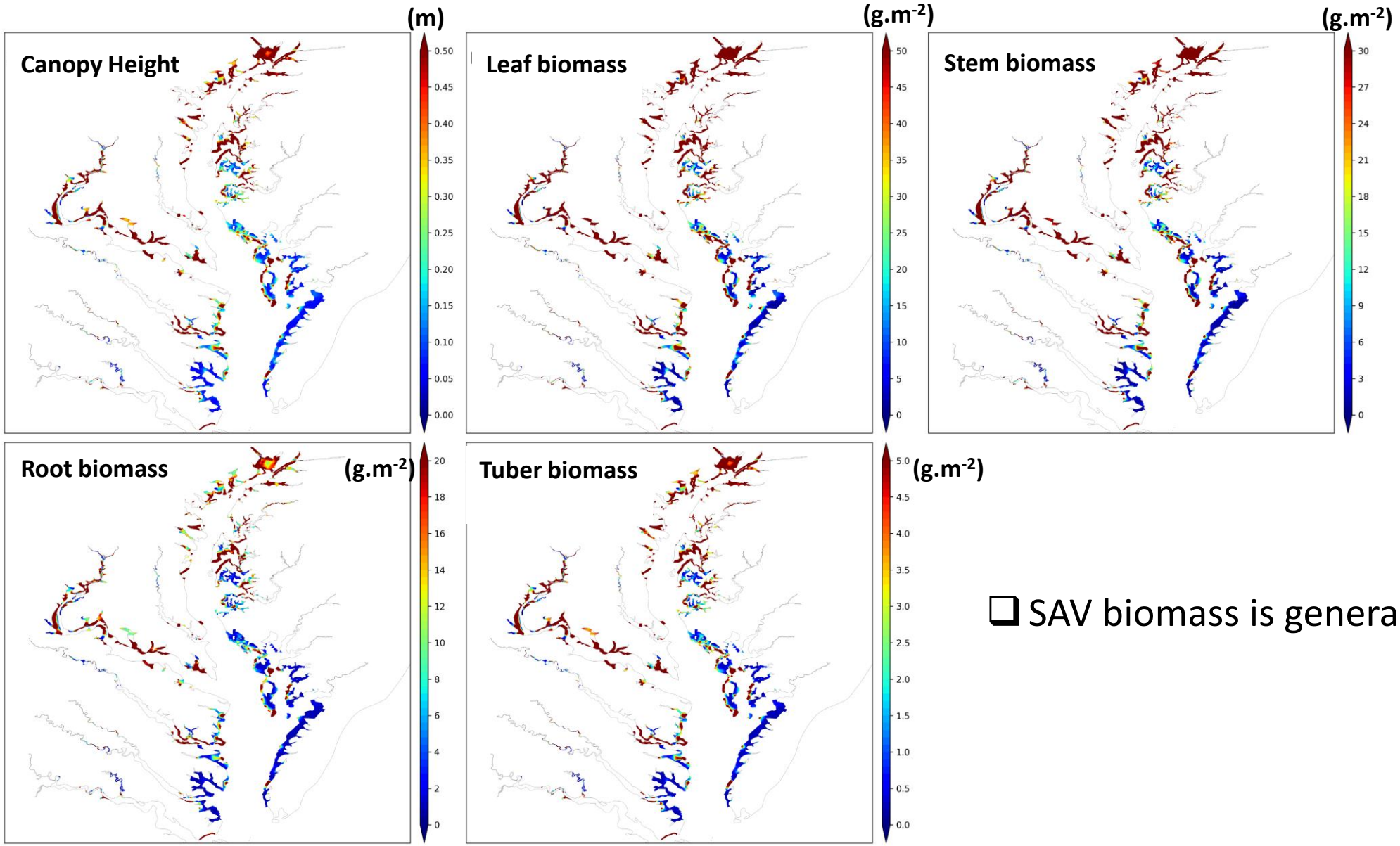
- Effects on the hydrodynamics
- Light attenuation by SAV leaf and stem
- Photosynthesis at SAV leaves
- Effects of temperate, light, nutrients
- Respiration of SAV leaf/stem/root
- Interaction with water column variables
- Interaction with sediment layer

SAV parameters in ICM

```
!-----------------------------------------------------------------------
!Submerged Aquatic Vegetation (SAV) parameters
!
spatch0 = -999                      !region flag for SAV. (1: ON all elem.; -999: spatial)
sFc     = -999                       !SAV bed fraction [0,1]
iMTs    = 1                         !1:1st-order metabolism;  2: 2nd-order metabolism formulation
sav0    = 30.0  30.0  30.0  10.0    !init. SAV leaf/stem/root/tuber conc. (g[C].m-2)

!growth coefficients
sGPM  = 0.3                      !maximum growth rate (day-1)
sTGP  = 32                       !optimal growth temperature (oC)
sKTGP = 0.003  0.005             !temp. dependence for growth (T<=sTGP & T>sTGP)
sFAM  = 0.2                      !fraction of leaf production to active metabolism
sFCP  = 0.55   0.3   0.1   0.05  !fractions of production to leaf/stem/root/tuber biomass

!metabolism coefficients
sMTB  = 0.02   0.02   0.02  0.02  !metabolism rates of leaf/stem/root/tuber (day-1)
sTMT  = 20     20     20    20    !reference temp. for leaf/stem/root/tuber metabolism (oC)
sKTMT = 0.069  0.069  0.069 0.069 !temp. dependence of leaf/stem/root/tuber metabolism (oC-1)
sFCM  = 0.9    0.08   0.01  0.01  !fractions of metabolism leaf/stem C into (RPOC,LPOC,DOC,CO2)
sFNM  = 0.5    0.3    0.1   0.1   !fractions of metabolism leaf/stem N into (RPON,LPON,DON,NH4)
sFPM  = 0.5    0.3    0.1   0.1   !fractions of metabolism leaf/stem P into (RPOP,LPOP,DOP,PO4)
sFCMb = 0.65   0.255  0.095 0.0   !fractions of metabolism root C into (G1/G2/G3 POC, CO2) in sediment
sFNMb = 0.65   0.300  0.050 0.0   !fractions of metabolism root N into (G1/G2/G3 PON, NH4) in sediment
sFPMb = 0.65   0.255  0.095 0.0   !fractions of metabolism root P into (G1/G2/G3 POP, PO4) in sediment

!misc. coefficients
sKTB   = 0.1               !mass transfer rate from tuber to leaves (day-1)
sDoy   = 60   150          !range of day_of_year for mass transfer of tuber
sKhN   = 0.01   0.1        !reference N conc. in water and sediment (mg/L)
sKhP   = 0.00001  0.00001  !reference P conc. in water and sediment (mg/L)
salpha = 0.012             !init. slope of P-I curve (g[C].m2.g[Chl]-1.E-1)
sKe    = 0.045             !light attenuation from leaf/stem absorption (g-1[C].m2)
shtm   = 0.054  2.0        !minimum (base) and  maximium canopy height (m)
s2ht   = 0.0036 0.0036 0.0 !coeffs. converting (leaf,stem,root) to canopy height (g-1[C].m3)
sc2dw  = 0.38              !carbon to dry weight ratio of sav
sn2c   = 0.02              !nitrogen to carbon ratio of sav
sp2c   = 0.005             !phosphorus to carbon ratio
savm   = 1.0  1.0  1.0  0.2   500.0  500.0  500.0  100  !minimum and maximum SAV leaf/stem/root/tuber conc
```

Simulated SAV in MBM: spatial variation

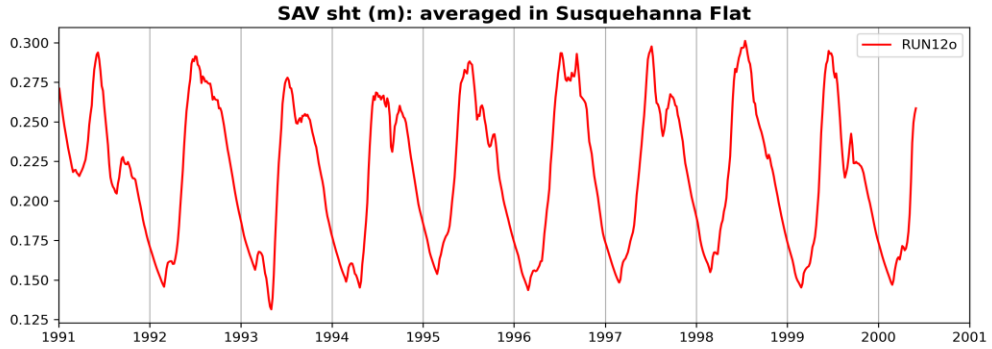
❑ The canopy height and SAV biomass are calculated by ICM

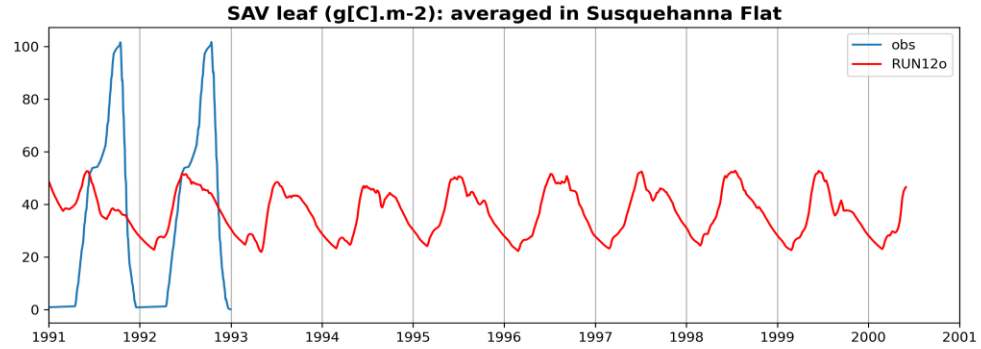


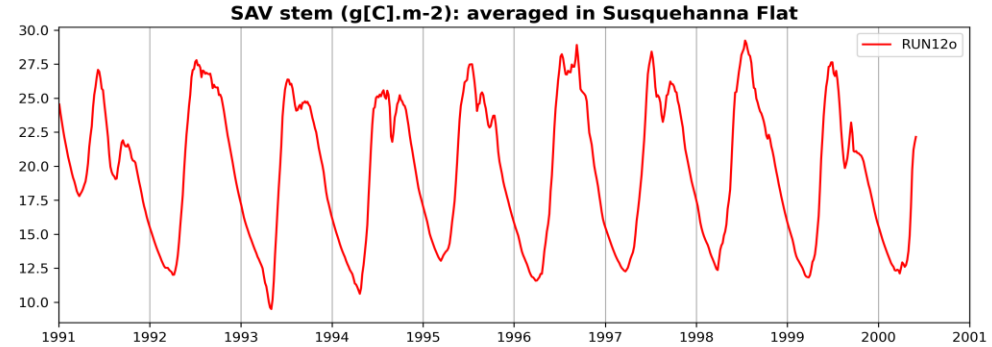
❑ SAV biomass is generally larger in upper Bay

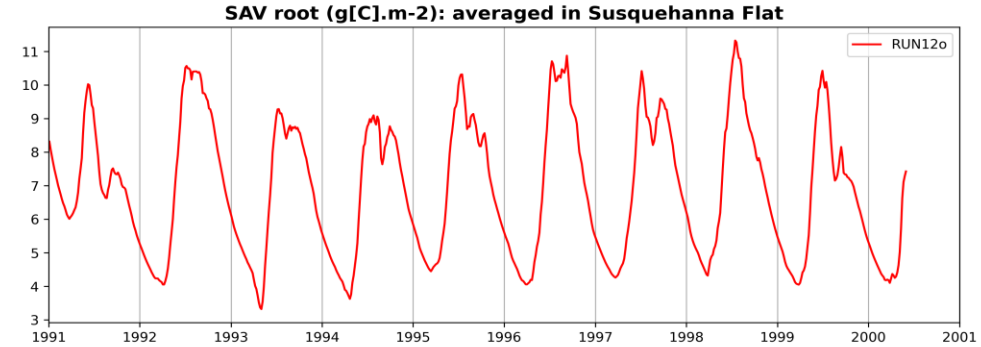
Simulated SAV in MBM: temporal variation

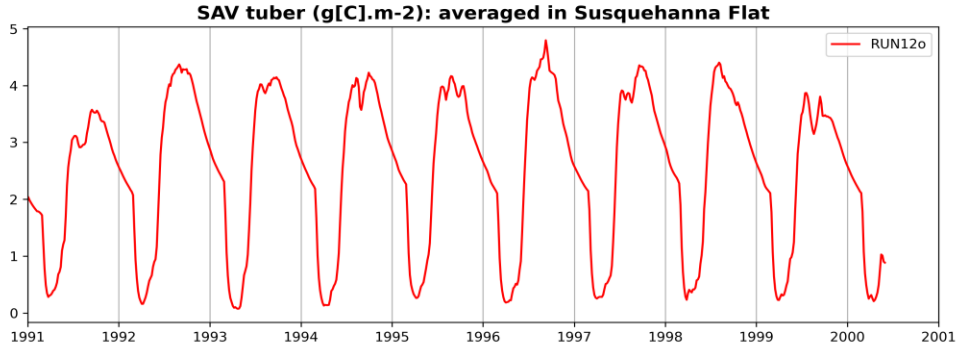
- In Susquehanna Flat, SAV biomass shows seasonal cycles. However, the seasonal variation in SAV leaf is lower than observations.
- More observational data is needed to further calibrate the SAV model.





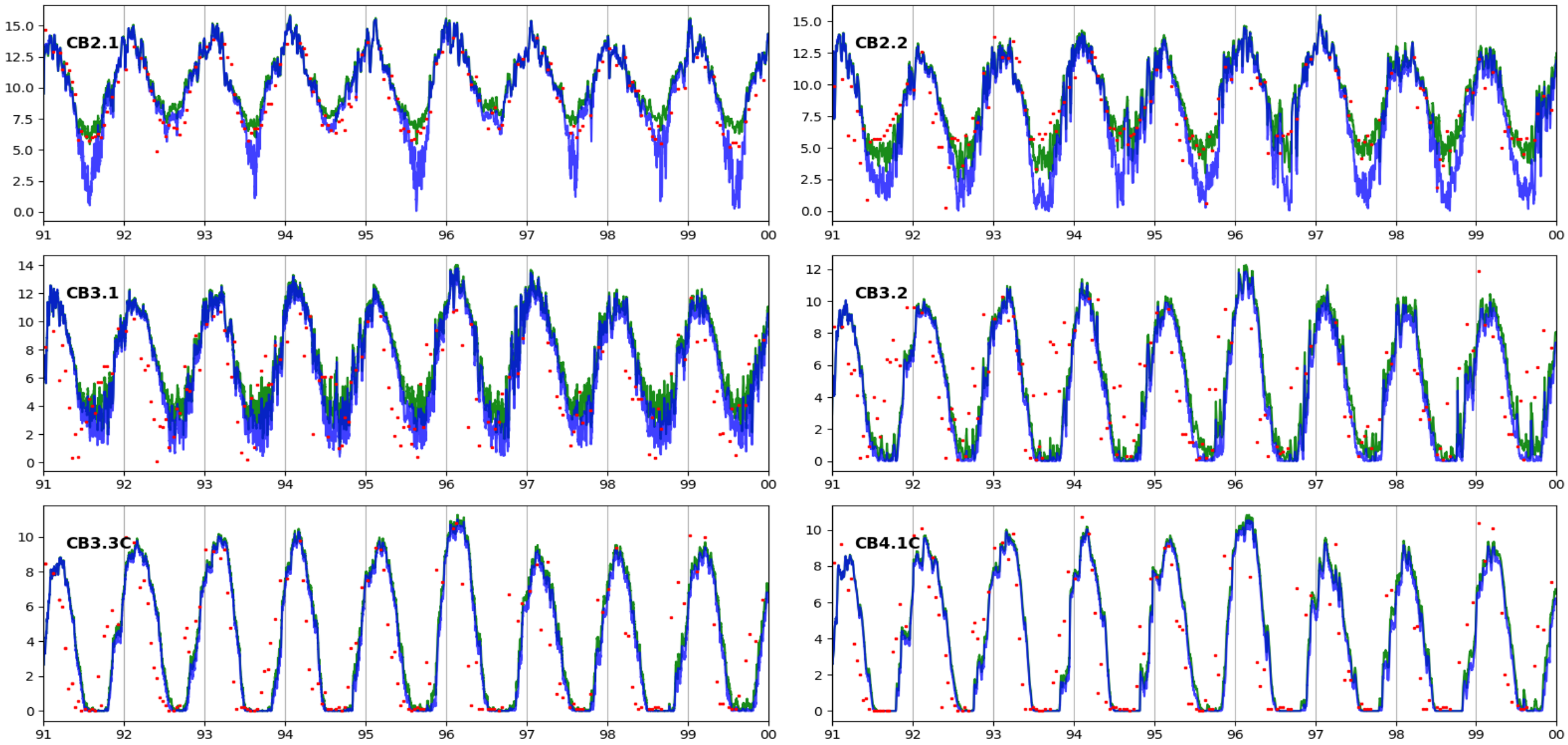






SAV Effects on Bottom DO

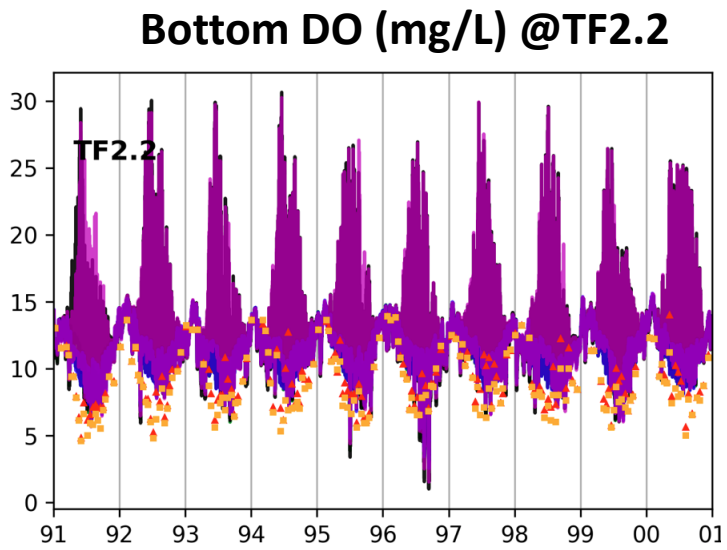
- With SAV included, the simulated DO becomes lower (results are sensitive to the routing of SAV biomass to different carbon species).
- Simulated DO is mostly improved with SAV at nearby stations

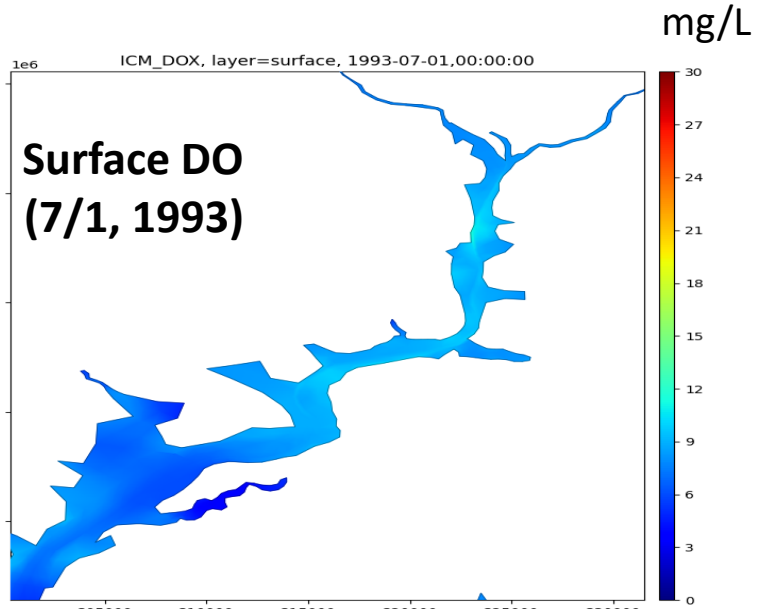


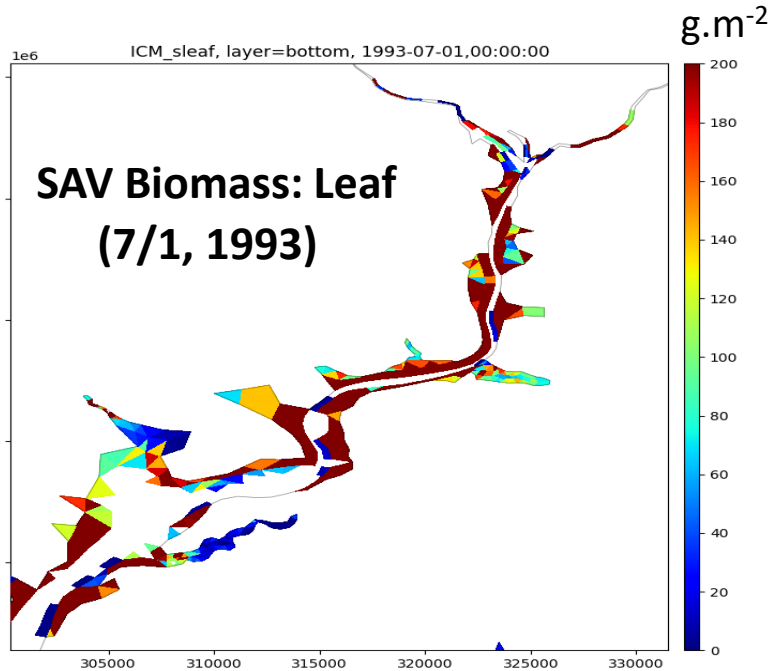
Previous Issue #1 in SAV Modeling: Supersaturation Of DO In Bottom Water

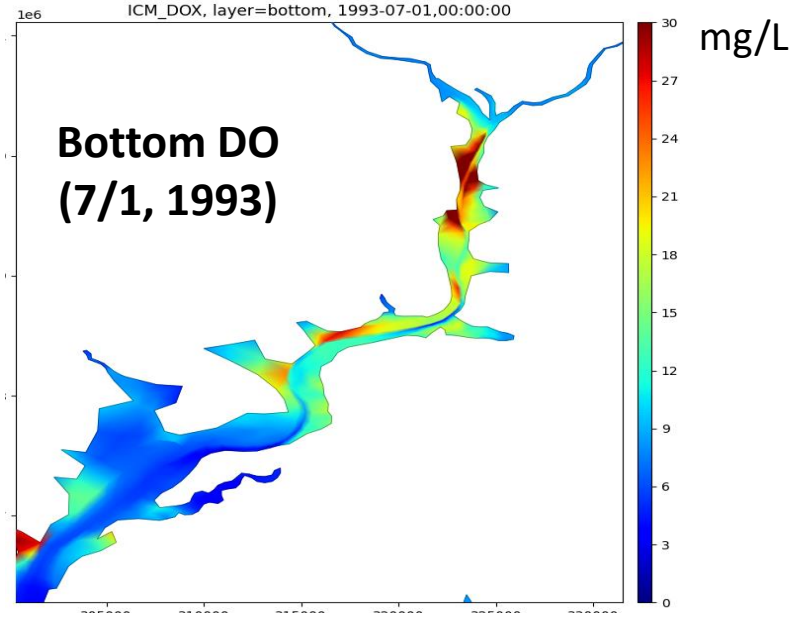
- Previous model with SAV produced supersaturation of DO in bottom water.
- Analyses of SAV processes revealed that the high bottom DO was due to the SAV photosynthesis producing too much oxygen in the bottom water.

High SAV biomass, and lower surface DO in upper Potomac River



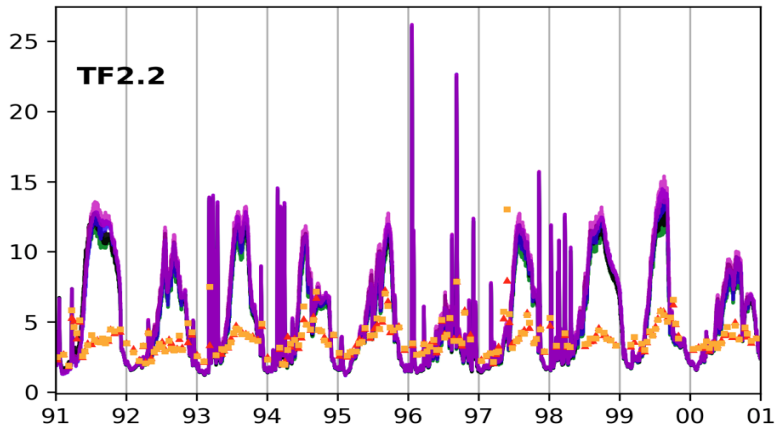


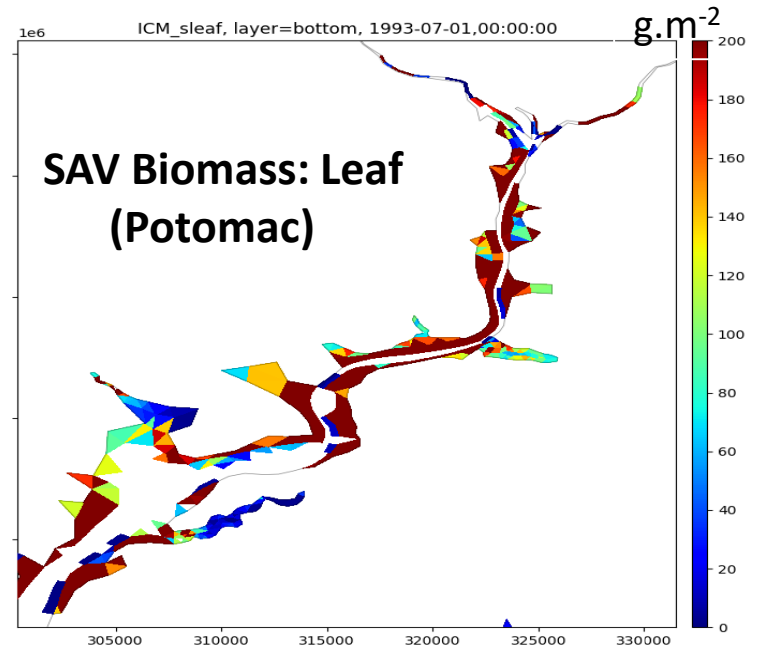


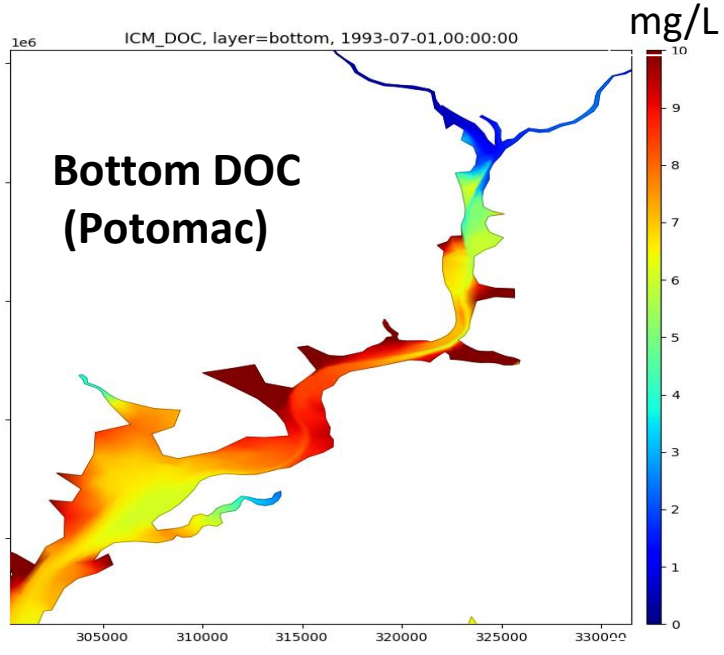


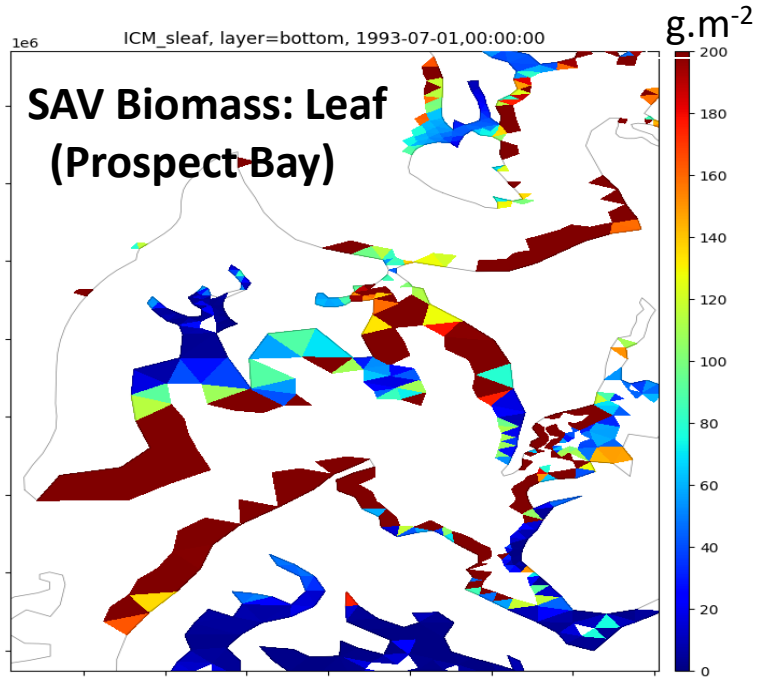
Previous Issue #2 in SAV Modeling: Too Much DOC Exported From SAV bed

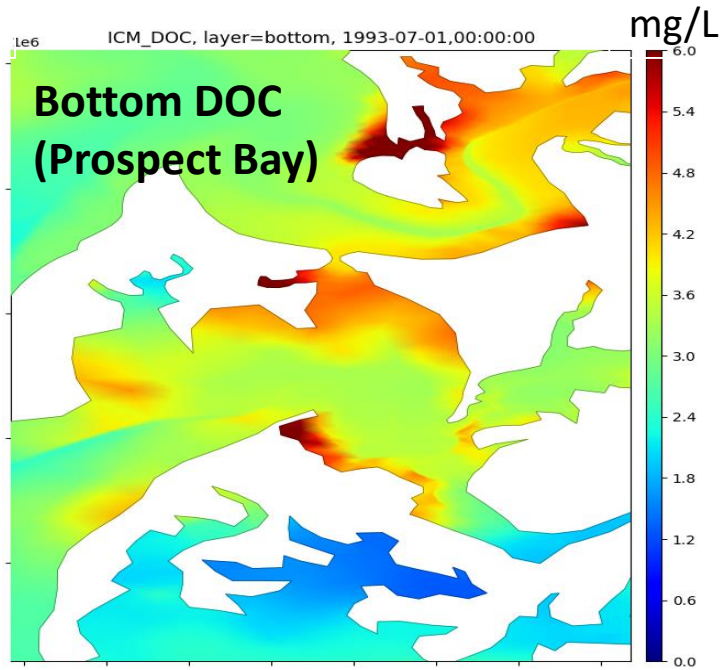
- High concentration of DOC occurred when SAV is included





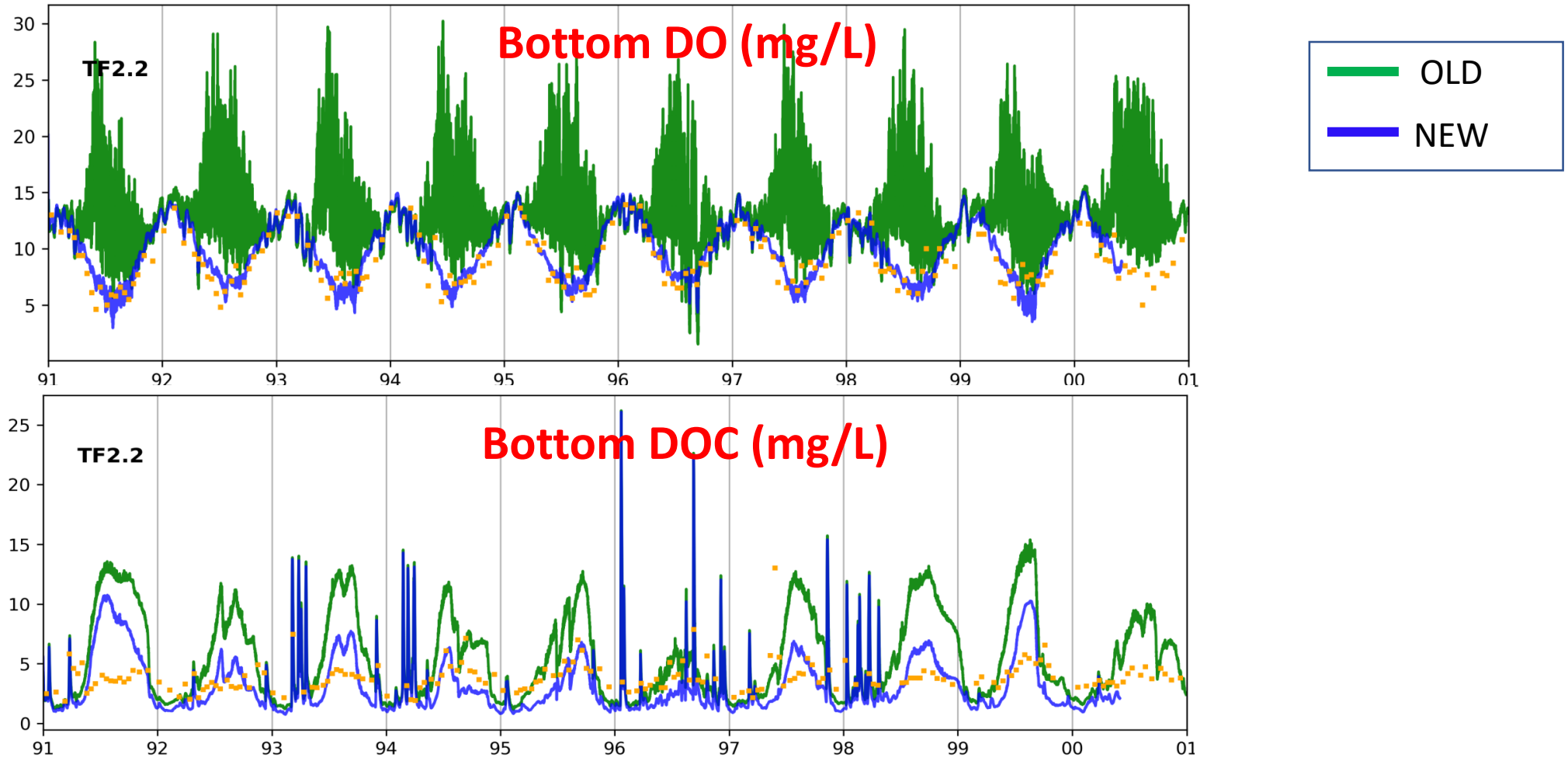






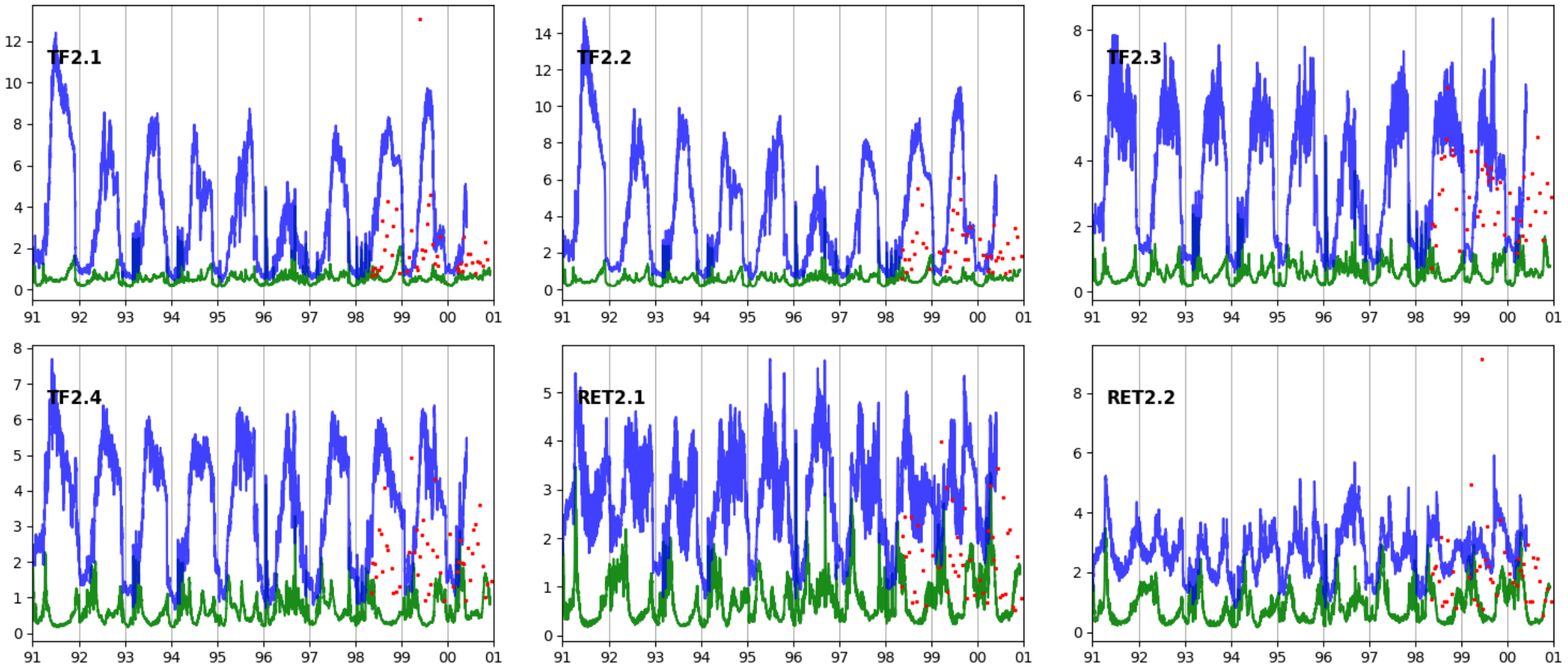
Calibration of SAV dynamics to reduce DO/DOC

- ❑ When SAV produces too much DO beyond saturation, we allow the DO to escape as gaseous form.
- ❑ Route more organic from DOC to POC in SAV process
- ❑ With these changes, the latest simulation shows better DO/DOC results.



SAV dynamics: organic matter exported from SAV bed

- Routing more organic from DOC to POC by SAV also improved the POC simulation in Potomac River!



Summary and Future Work on SAV modeling in MBM

- MBM includes a sophisticated vegetation model, integrating physical and biological processes to provide a holistic view of SAV's role in the Chesapeake Bay, especially in the shallow-water habitats.

- SAV beds help reduce current speed, wave height, diffusivity, and thus total suspended solids.

- SAV growth exhibits a clear seasonal cycle, with higher biomass computed in the upper Bay.

- SAV bed tends to reduce bottom oxygen levels, while exporting organic matter.

- Moving forward, additional SAV observations are needed to further constrain the model.

- We will continue to explore more shallow-water capabilities of MBM with other living resource modules for future scenarios.