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Improving Estuarine Conditions in Biscayne Bay by Optimizing the Timing and Distribution of Freshwater Discharge

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The Model

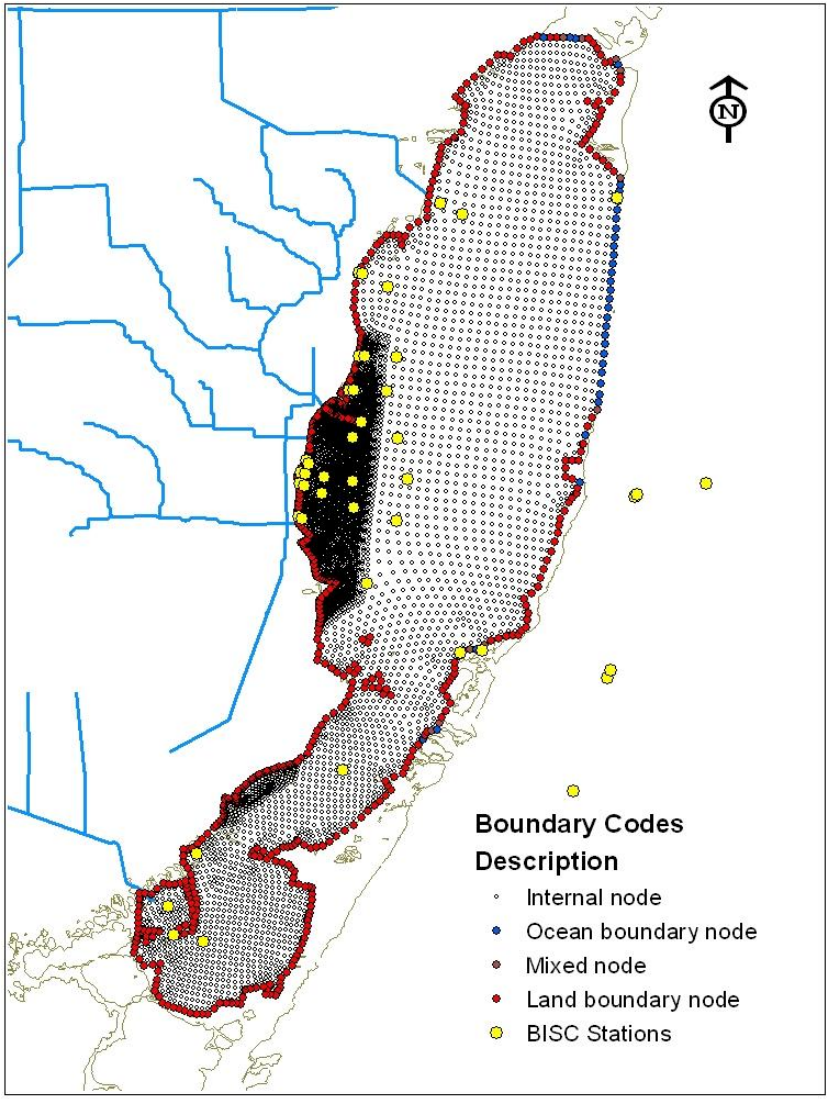
- Model developed by John Wang, in various forms since late 70's. General name = CAFE3D
  - Current implementation is single layer
  - Fortran
- Model has been used in Biscayne Bay to:
  - determine residence times for various locations in the bay
  - evaluate the effect of restoration alternatives with respect to salinity
  - investigate connectivity between basins

Objectives with the model

- Biscayne Bay is a modified environment with respect to freshwater flow
  - Limited flow and altered distribution
  - Altered timing with respect to seasons
  - Altered connectivity with open ocean

- Modeling salinity changes due to current projects
  - Changes in location, timing, and duration of discharge
  - Changes in velocity at discharge source

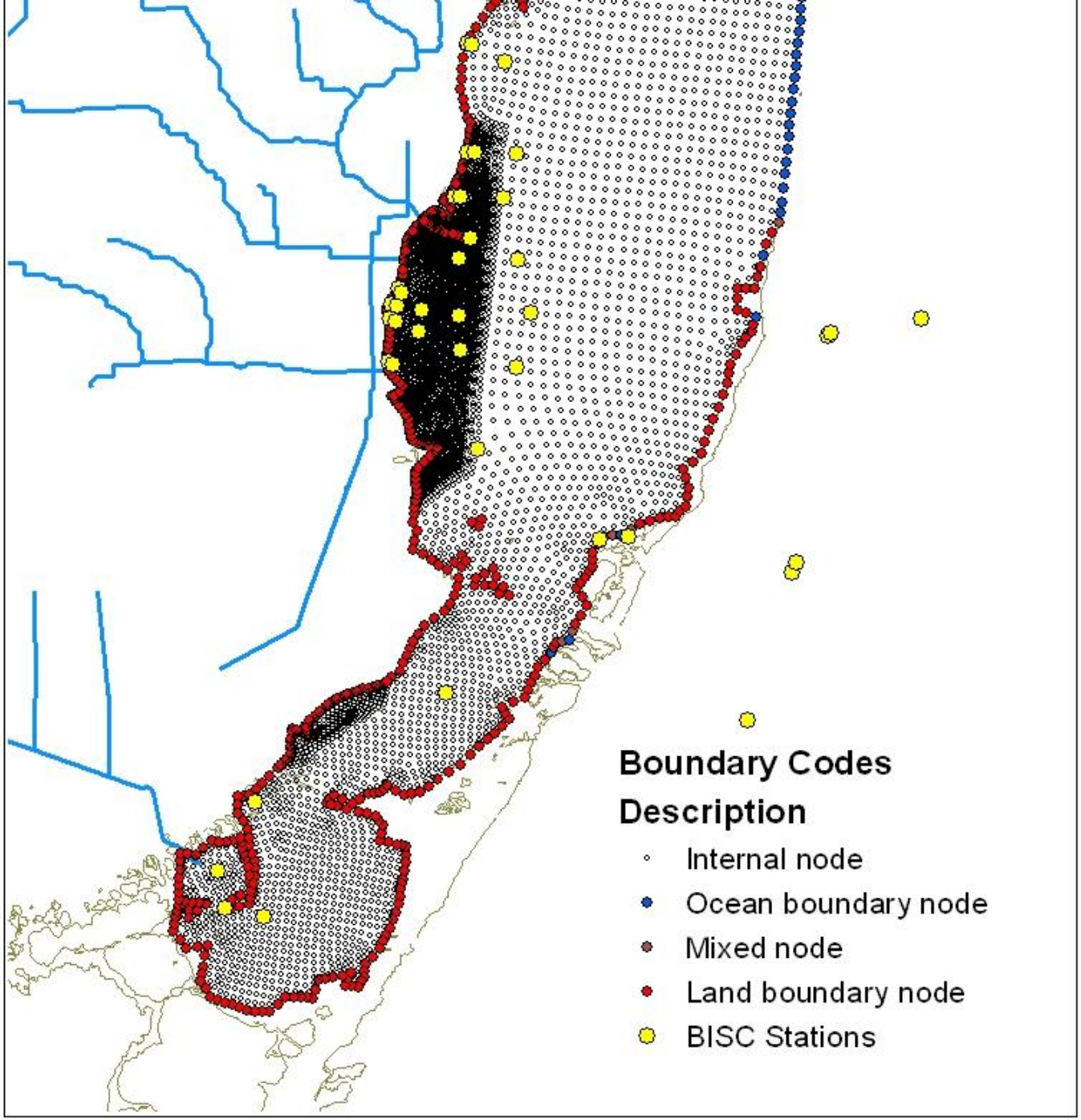
Biscayne Bay Simulation Model

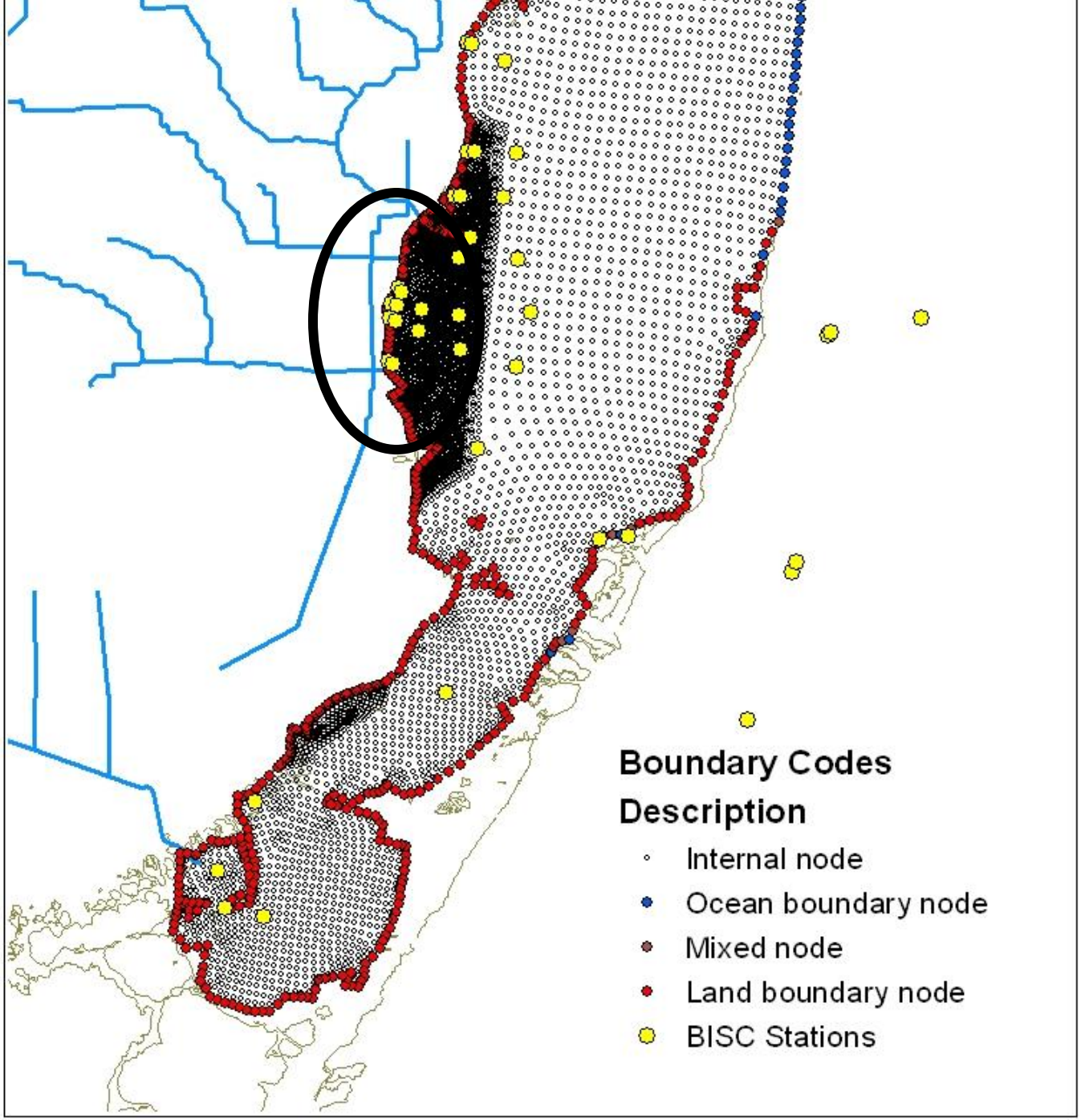


Predicting salinity regime under alternate discharge scenarios

BBSM model with:

- Advection and diffusion
- Rain and evaporation
- Wind stress
- Bottom friction
- Tidal mixing
- Surface water inflows*
- Control on boundary conditions
- 10 years (1996 – 2005) at 20 minute resolution
- Model processing time = 37 hours


Boundary Codes
Description
Internal node
Ocean boundary node
Mixed node
Land boundary node
BISC Stations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Basic equations (test to follow)

Continuity.—

$$\frac{\partial H}{\partial t} + \frac{\partial q_x}{\partial x} + \frac{\partial q_y}{\partial y} = q_{in}$$

$$q_x = \int_{-h}^{\eta} u \, dz; \quad q_y = \int_{-h}^{\eta} v \, dz$$

Plain language: mass balance

Change in volume and x, y flow components as a function of horizontal flux in/out and change in water column height

Wang, Luo & Alt, Bulletin of Applied Marine Science, 72(3), p. 695-723, 2003

Basic equations

Momentum.—

$$\frac{\partial q_x}{\partial t}+\frac{\partial u q_x}{\partial x}+\frac{\partial v q_x}{\partial y}=-gH\frac{\partial \eta}{\partial x}-\frac{gH^2}{2\rho}\frac{\partial \delta\rho}{\partial x}+fq_y-C_f\mathbf{u}u-\frac{\tau_x}{\rho}+\frac{\partial}{\partial x}\left(HE_{xx}\frac{\partial u}{\partial x}\right)+\frac{\partial}{\partial y}\left[HE_{xy}\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)\right] \quad (3)$$

and

$$\frac{\partial q_y}{\partial t}+\frac{\partial u q_y}{\partial x}+\frac{\partial v q_y}{\partial y}=-gH\frac{\partial \eta}{\partial y}-\frac{gH^2}{2\rho}\frac{\partial \delta\rho}{\partial y}-fq_x-C_f\mathbf{u}v-\frac{\tau_y}{\rho}+\frac{\partial}{\partial x}\left[HE_{yx}\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)\right]+\frac{\partial}{\partial y}\left(HE_{yy}\frac{\partial v}{\partial y}\right) \quad (4)$$

Wang, et Al., BAMS, 72(3), p. 695-723, 2003

Basic equations

Momentum.—

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and

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Effect of gravity with change in water column height

Flow - friction

Wind stress

Eddie viscosity and mixing

Wang, et Al., BAMS, 72(3), p. 695-723, 2003

Basic equations

Advection-Diffusion.—

$$H\frac{\partial c}{\partial t} + uH\frac{\partial c}{\partial x} + vH\frac{\partial c}{\partial y} = \frac{\partial}{\partial x}\left(HD_{xx}\frac{\partial c}{\partial x} + HD_{xy}\frac{\partial c}{\partial x}\right) + \frac{\partial}{\partial y}\left(HD_{yx}\frac{\partial c}{\partial x} + HD_{yy}\frac{\partial c}{\partial y}\right) + q_{in}\left(c^{*} - c\right) + S^{*} \qquad (5)$$

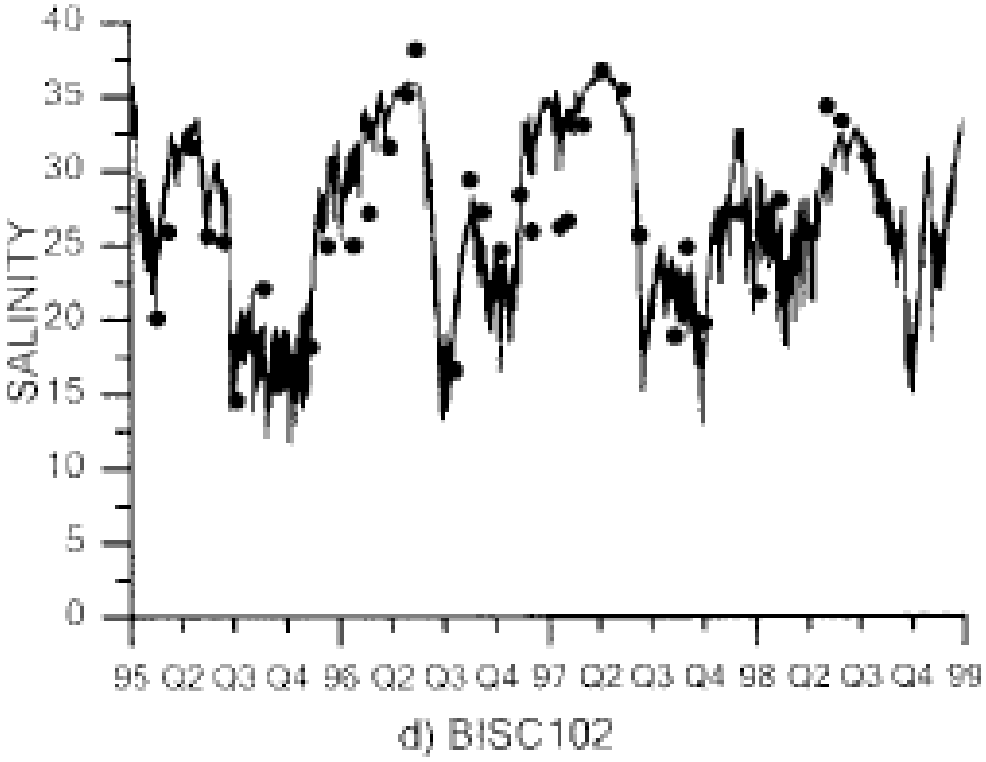
Addresses changes in density as function of changes in concentration

Wang, et Al., BAMS, 72(3), p. 695-723, 2003

Physical forcing

- Wind and reef-track wind data applied uniformly to whole bay. Hurricane related winds have been reduced.
- Precipitation from SFWMD local record, evaporation from station at Royal Palm in Everglades, applied as difference
  - approx. 166 cm / yr evap.
  - approx. 127 cm / yr precip.
- Tides set to Virginia Key with offset for each inlet down ocean side of bay
- Groundwater and overland flow initially from 2x2 but adjustable

Validation



Quarterly 1995 to 1999

EXAMPLE: Mid Biscayne Bay observed (dot) and model (line) hindcast

Validation

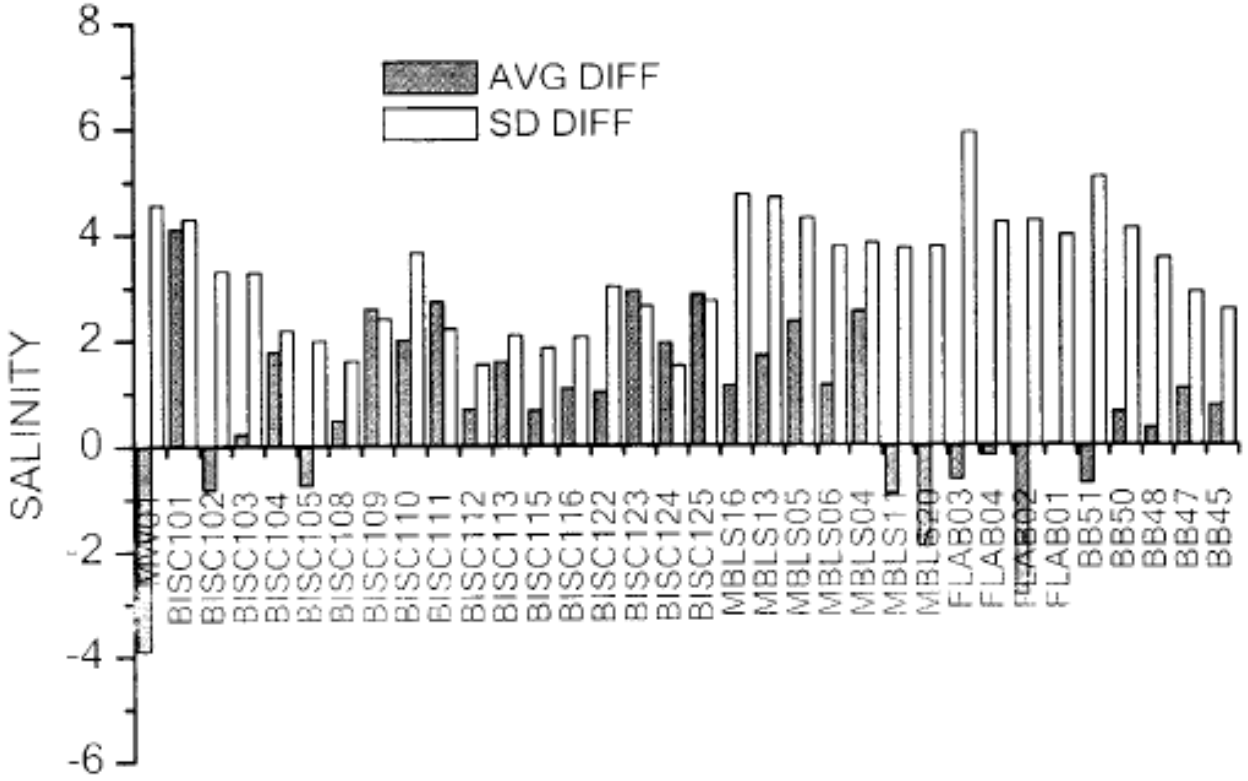


Figure 12. Statistics (average and standard deviation) of salinity differences for 1995–1998 model hindcast, 34 stations.

Model bias, model tends to have lower salinity than observations

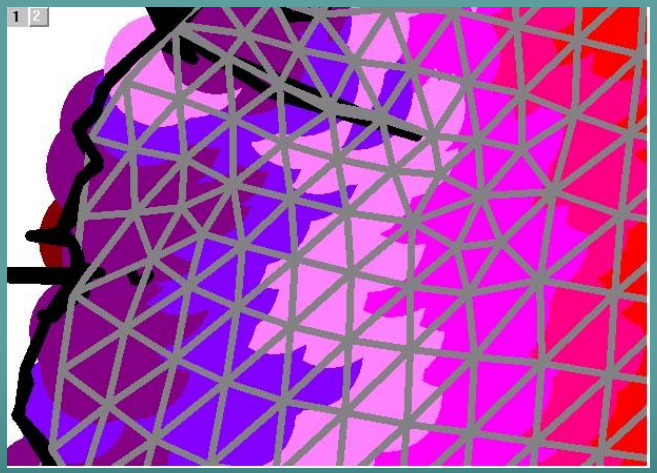
Larger differences near canal mouths – related to resolution of model.

TWO STAGES OF GRID REFINEMENT

3407 NODES

6364 ELEMENTS

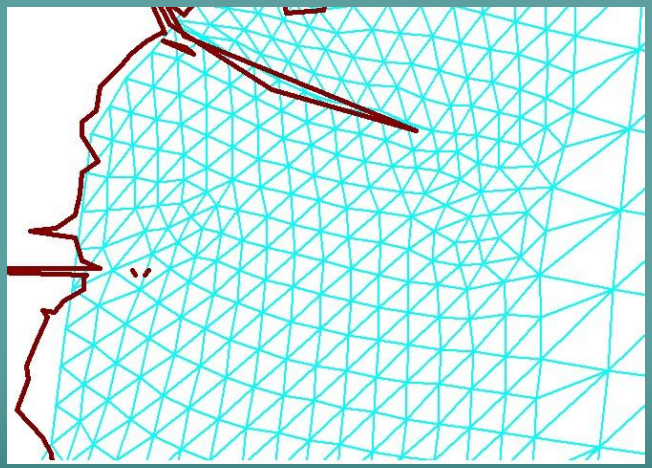
400 M



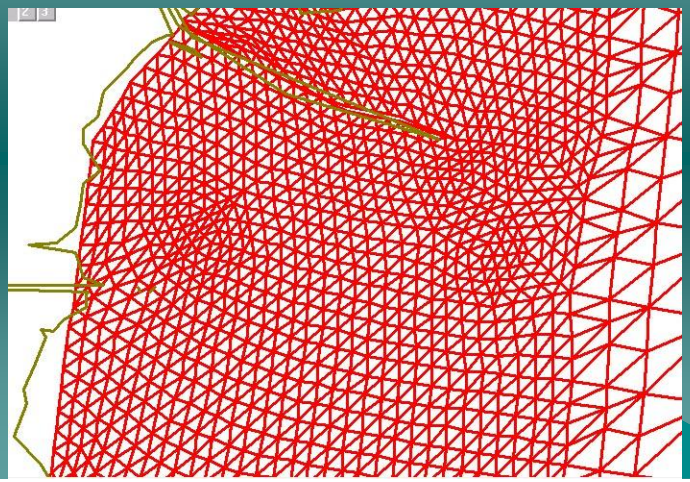
4050 NODES

7594 ELEMENTS

200 M



1000 M



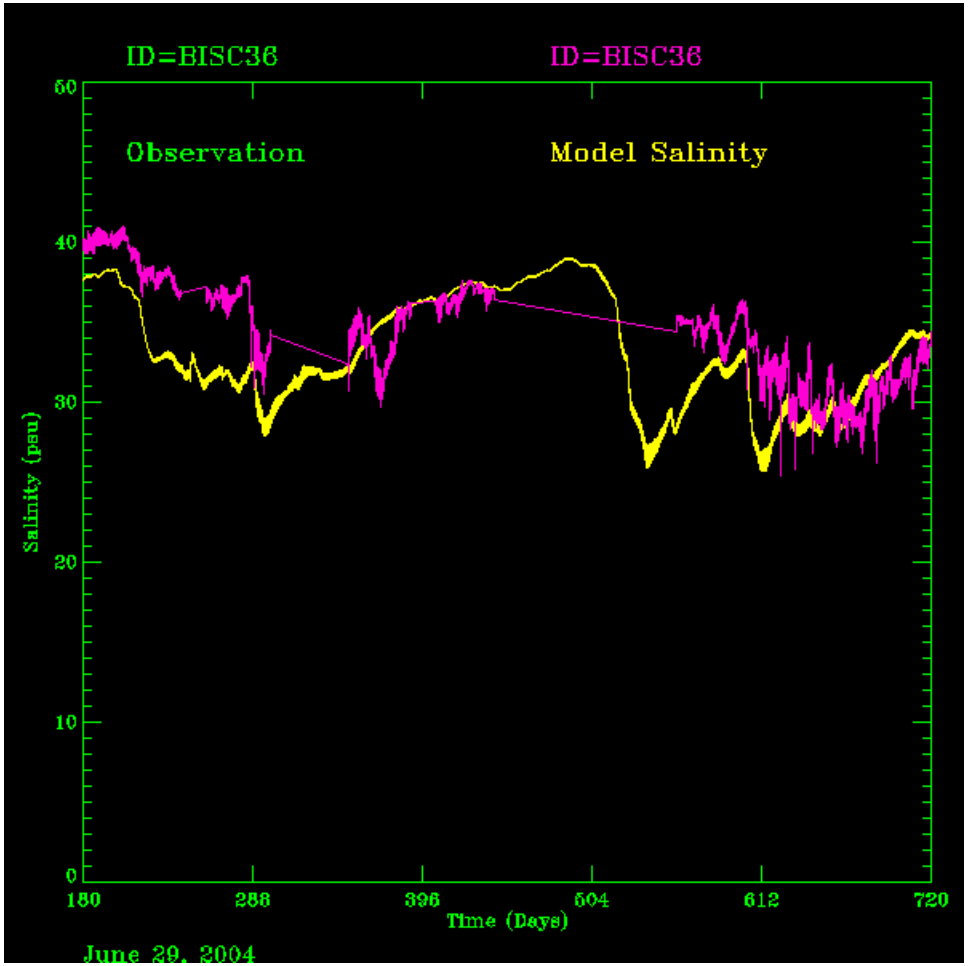
6857 NODES

13075 ELEMENTS

100 M

Validation – current form

Bottom



Current model viewer lacks rigorous validation and comparison tools

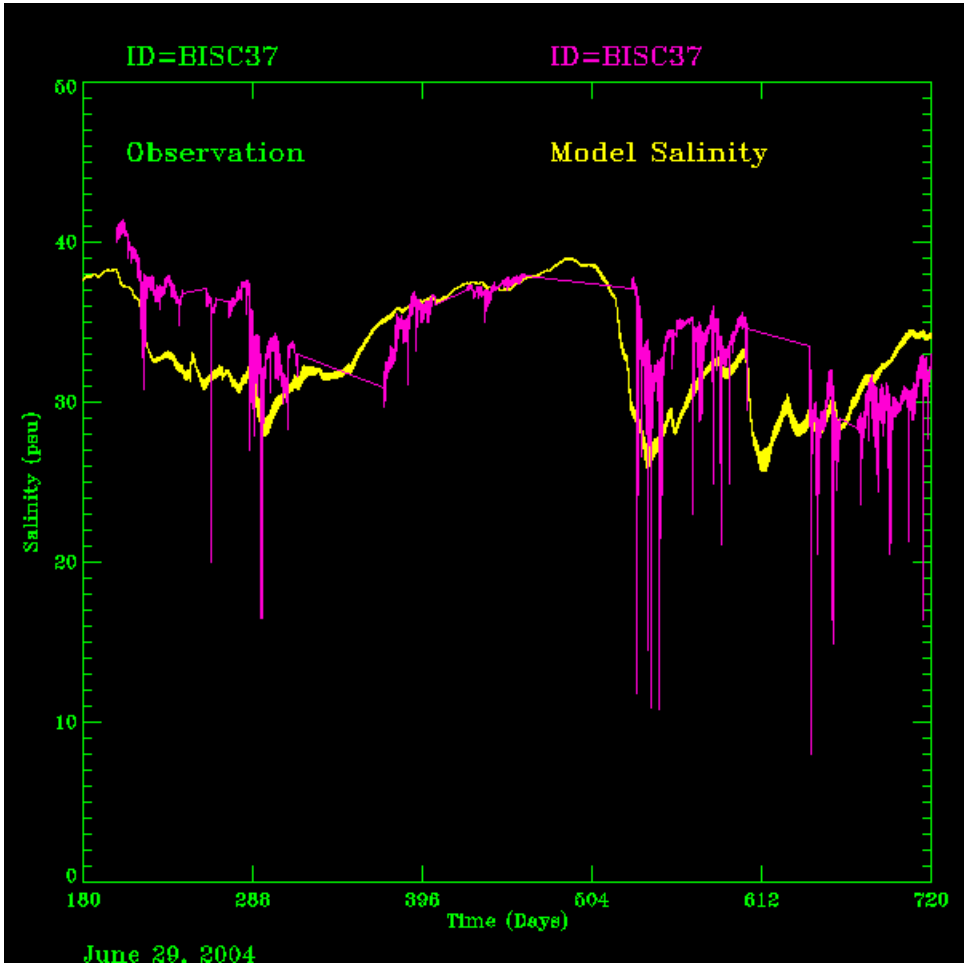
Next generation viewer, extraction tool includes:

- Simplified input selection
- Numeric integration of area/time
- Time series statistics

Also – observations are ongoing

Validation – current form

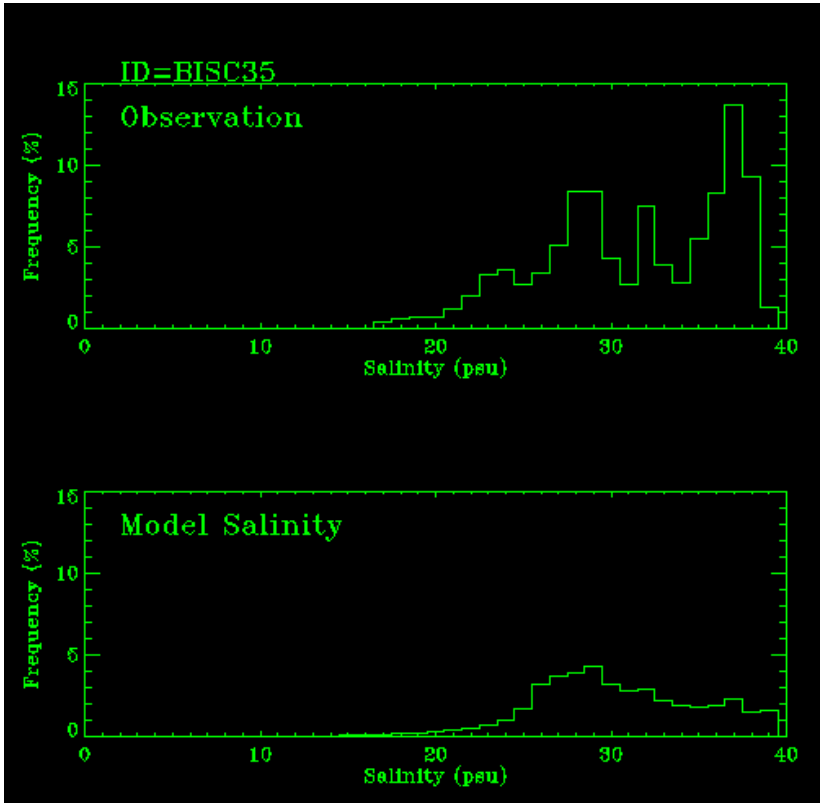
Surface



Low salinity spikes = rain or sensor out of water

Note that BISC36 & BISC 37 are on same model element

Model viewer output



Extraction in place

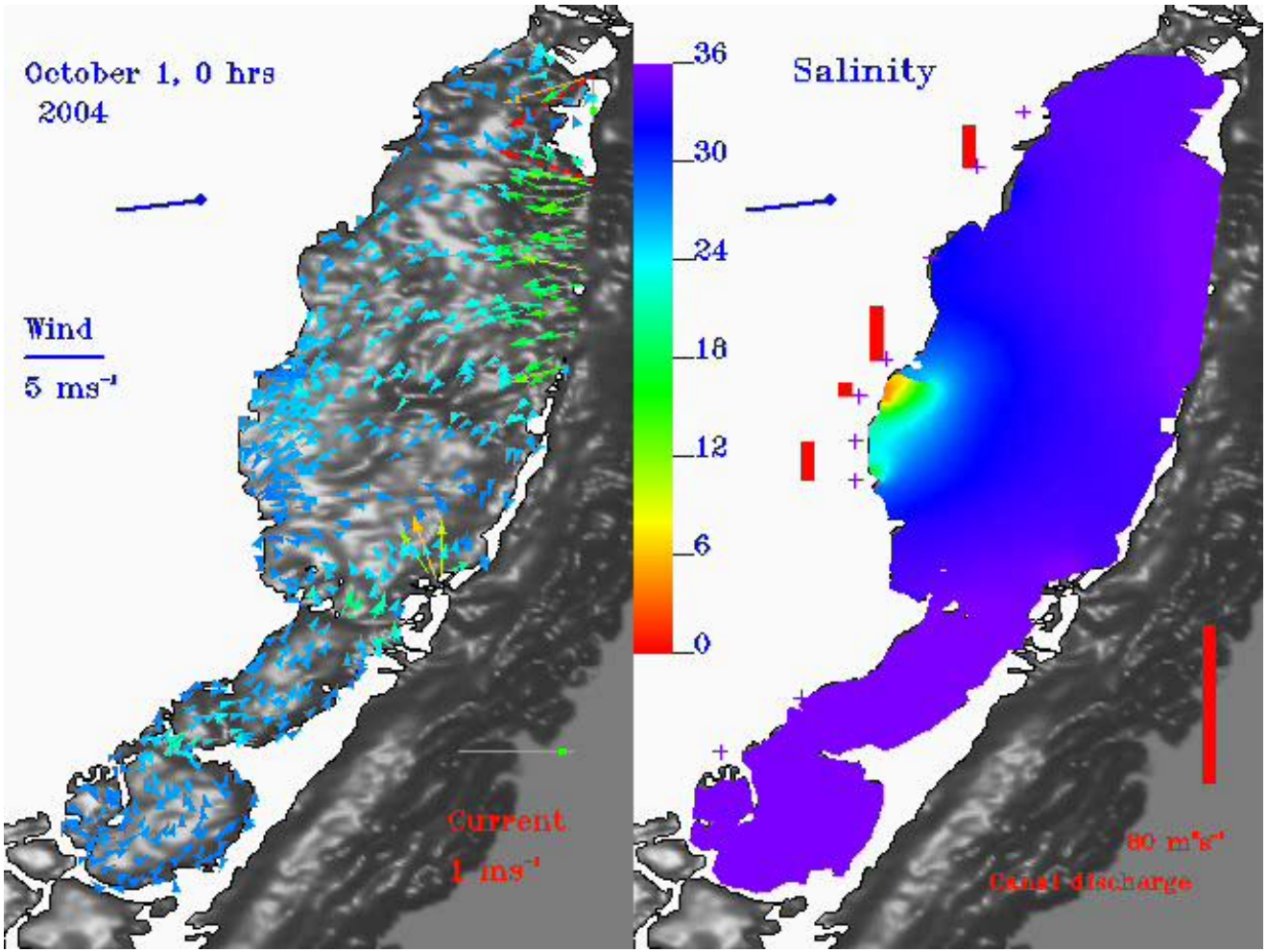
New model viewer under development

Model output stats

ID	N	Days	_	Mean	stdev	MinS	MaxS	Median	Mode	Skewnes	Kurtos	Absdev	%<10.	%>36.
BISC01	17544	731		35.54	5.2865	7.72	41.59	36.78	38.50	-2.0991	5.3142	3.5998	0.39	58.
BISC02	17544	731		35.91	4.1633	16.89	41.36	36.80	38.50	-1.4536	2.0022	3.0550	0.00	58.59

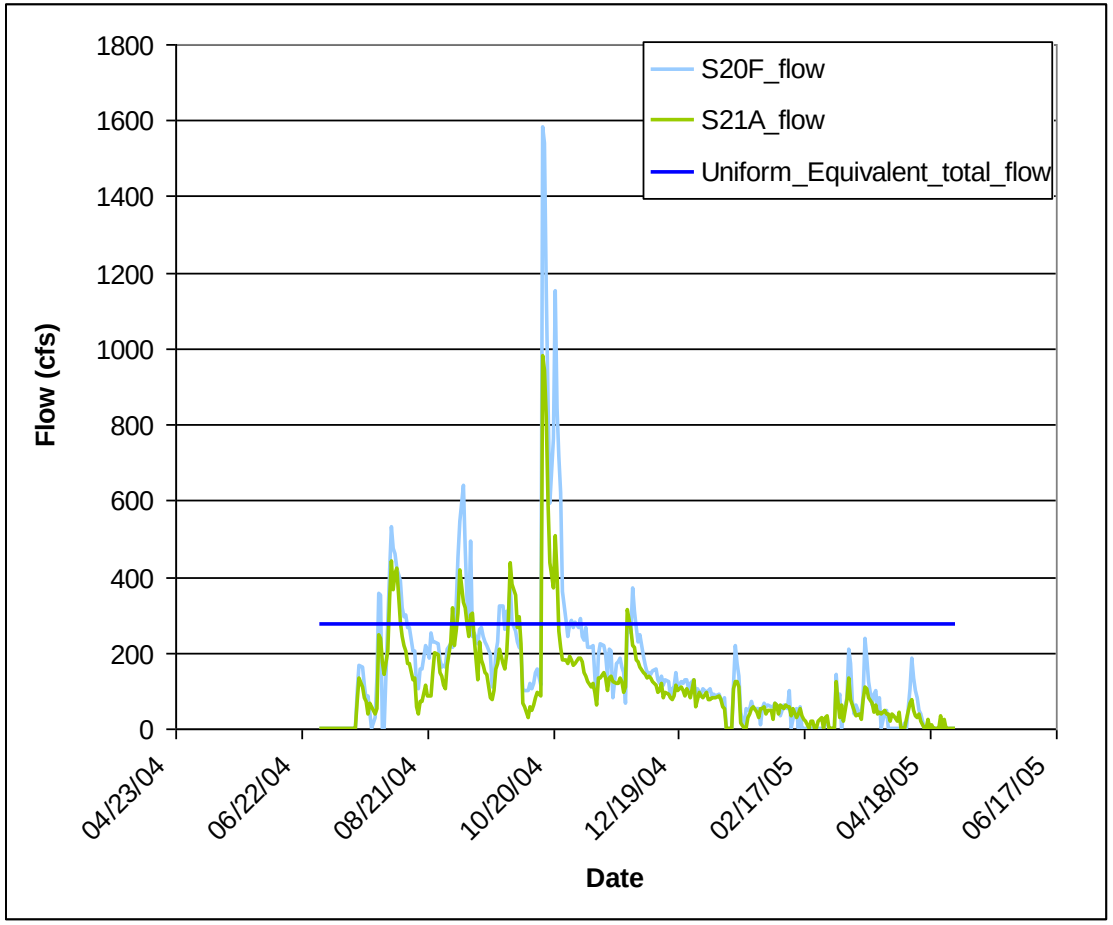
Biscayne Bay Simulation Model

Output: Flow and salinity field for each time step (hourly)



Evaluating Alterative Flow Regimes:

redistribute existing water



Constant temporal distribution

- Steady flow rate Oct. 15 to March 30
- Limitation: Requires additional storage
- Total water = 63 k acre ft

Changing spatial distribution

- 3 different model scenarios split the constant flow across different areas

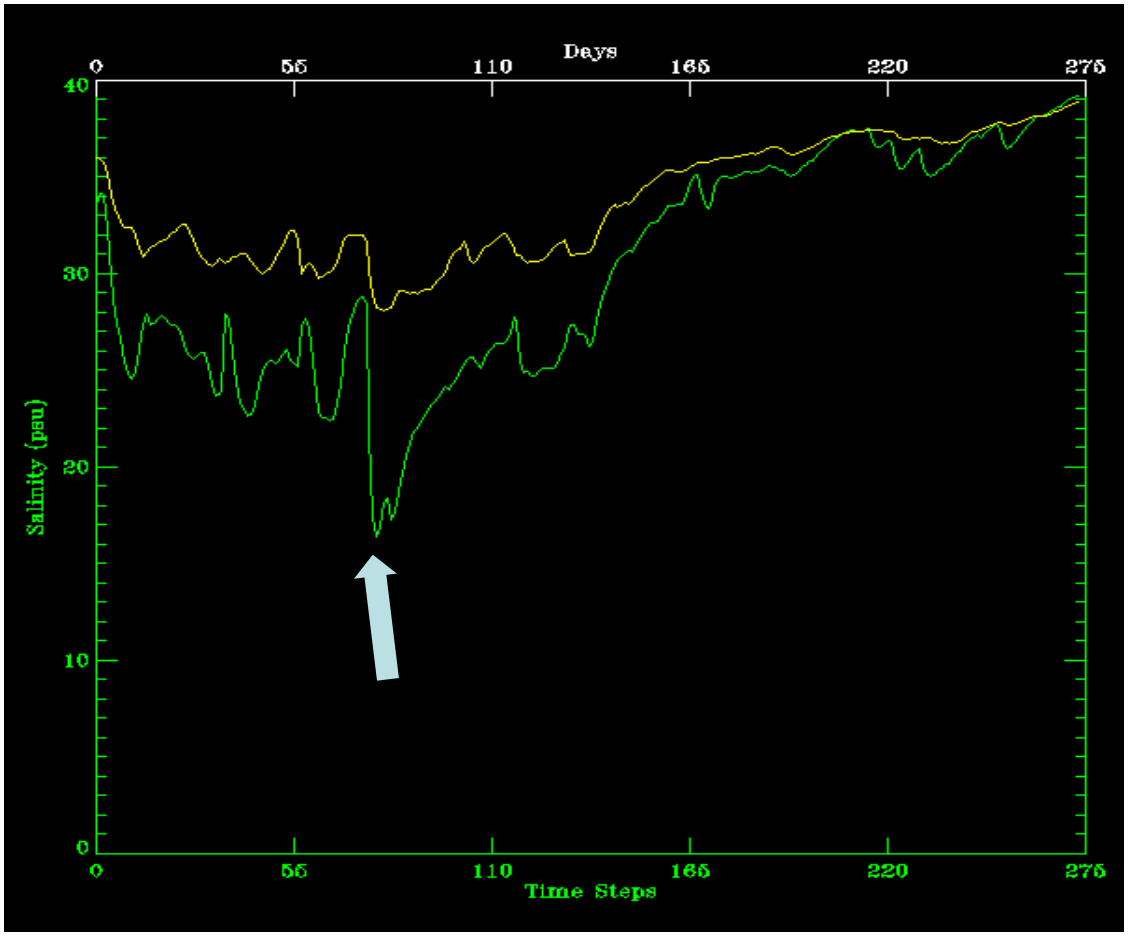
Goal:

- avoid hypersaline conditions
- Moderate rate of variation in salinity

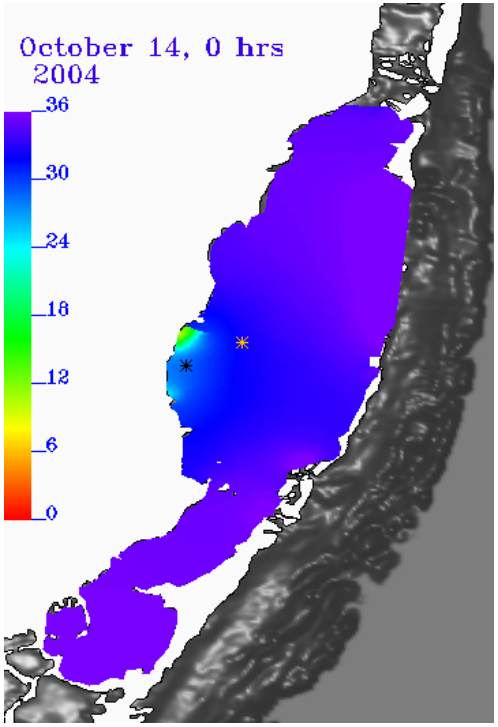
Modeled Scenarios

- Slow_ag
  - Water split between two canals (S21A, S20F), but outflow reduced to allow flow over an extended period from Oct. 15 to March 30th
- Culverts_ag
  - Water delivered via BBCW planned culverts in L31E near Florida City Canal to regions north of C102
- Redistributed_ag
  - Water delivered through culverts as above and through three canal structures (S20F, S21A, and Military Canal)

Modeled Results – Base Conditions

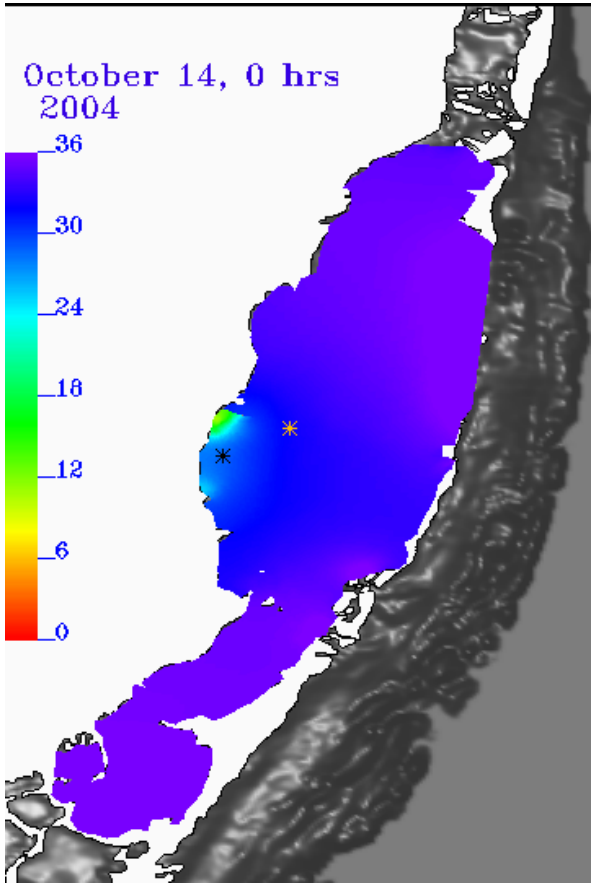


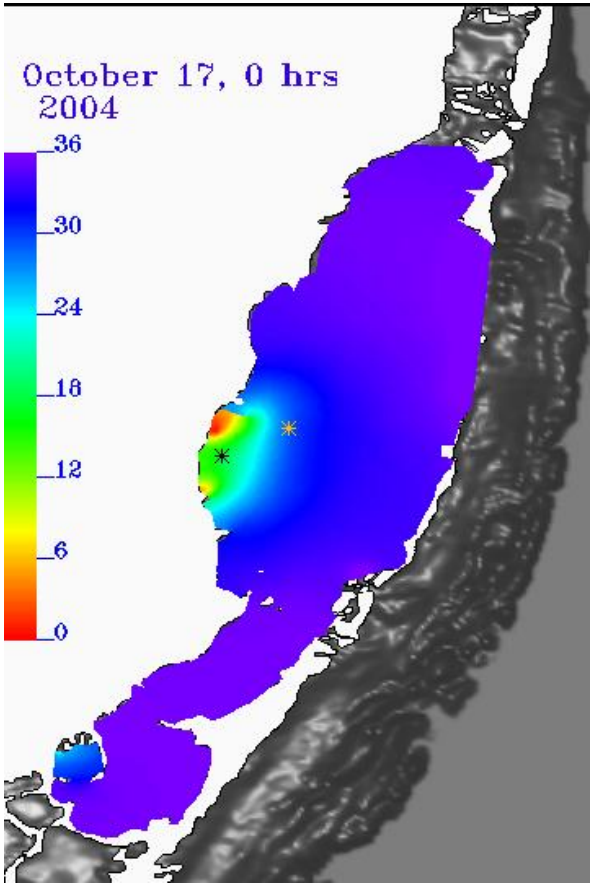
Distribution

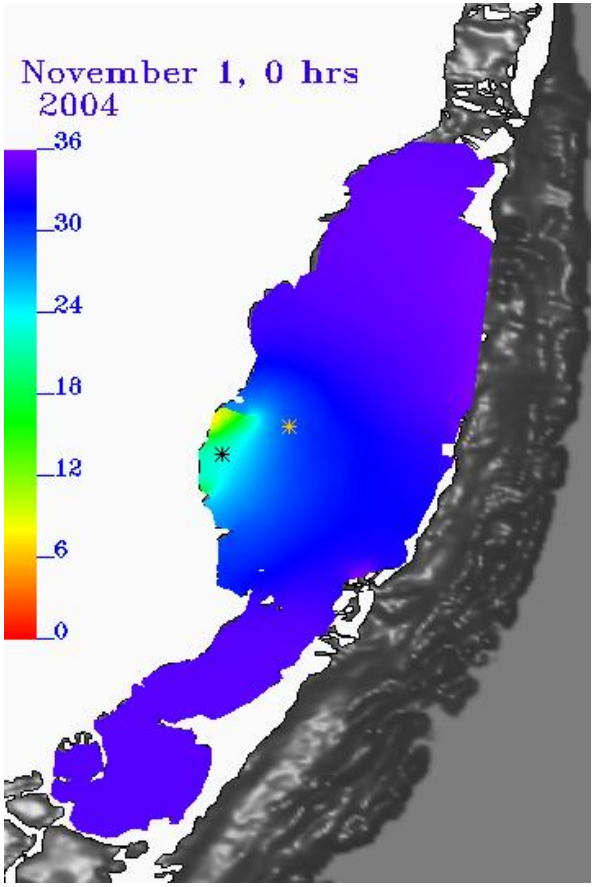


Modeled Results – Base Conditions

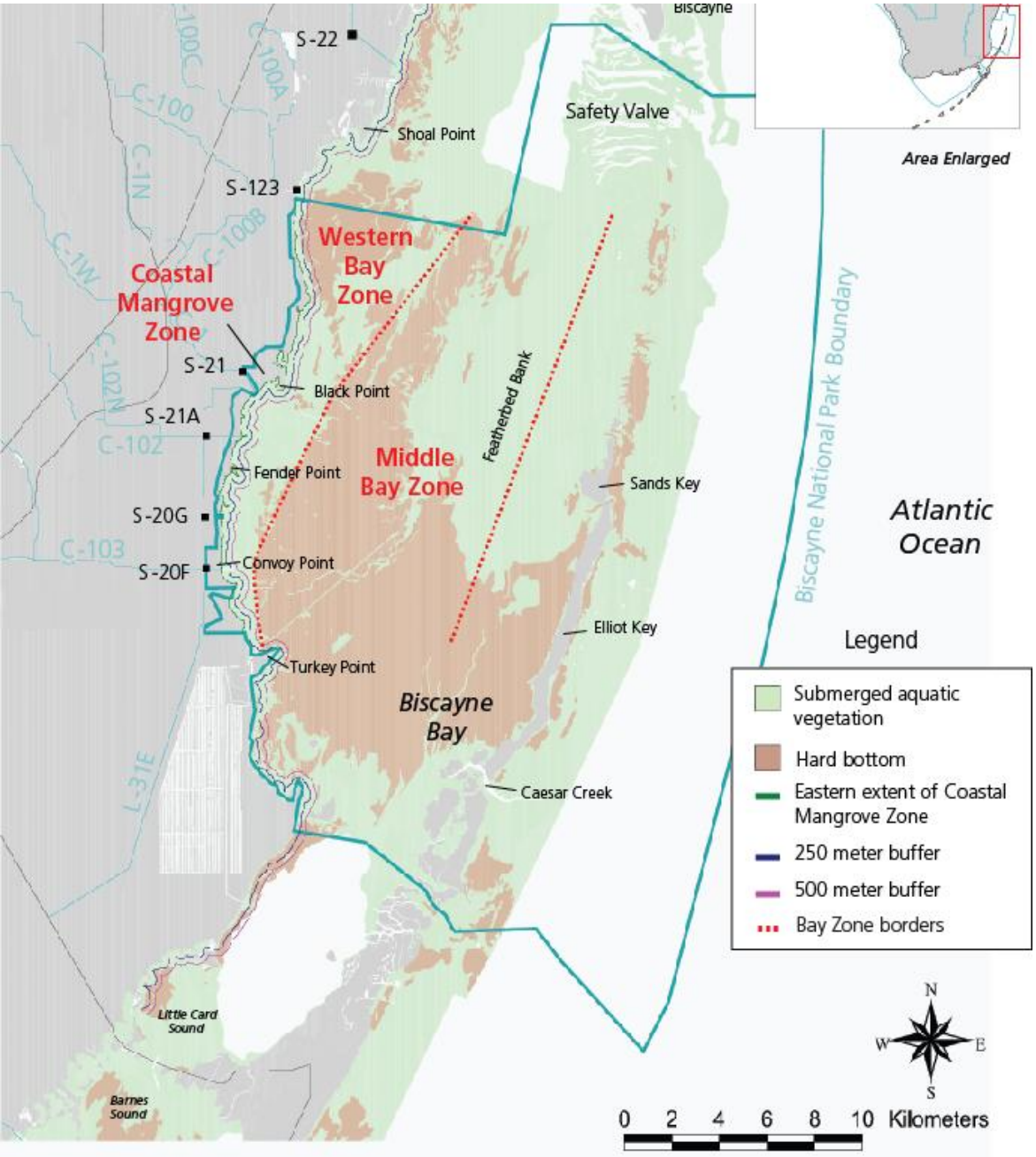
Pre-release → During Ag-drawdown → Two weeks into low range operations



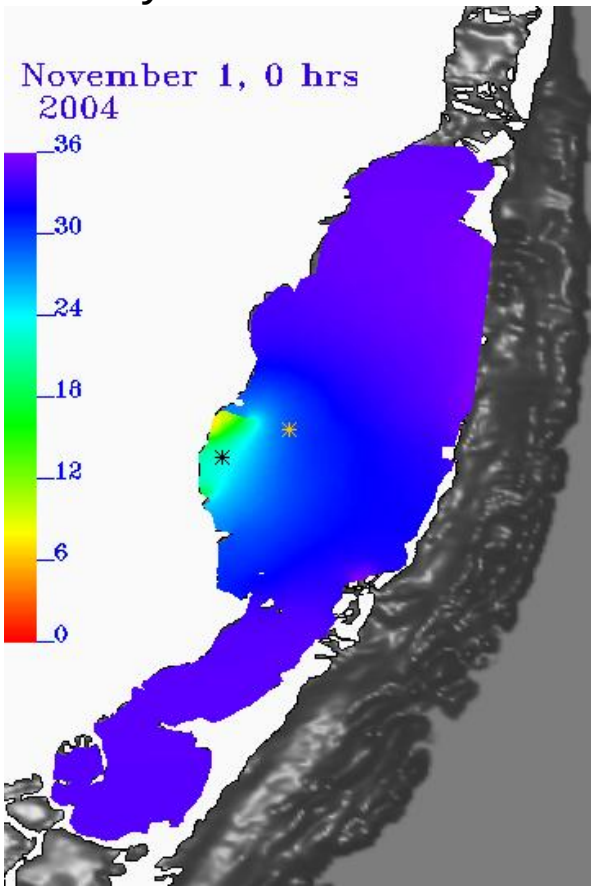




Modeled Results

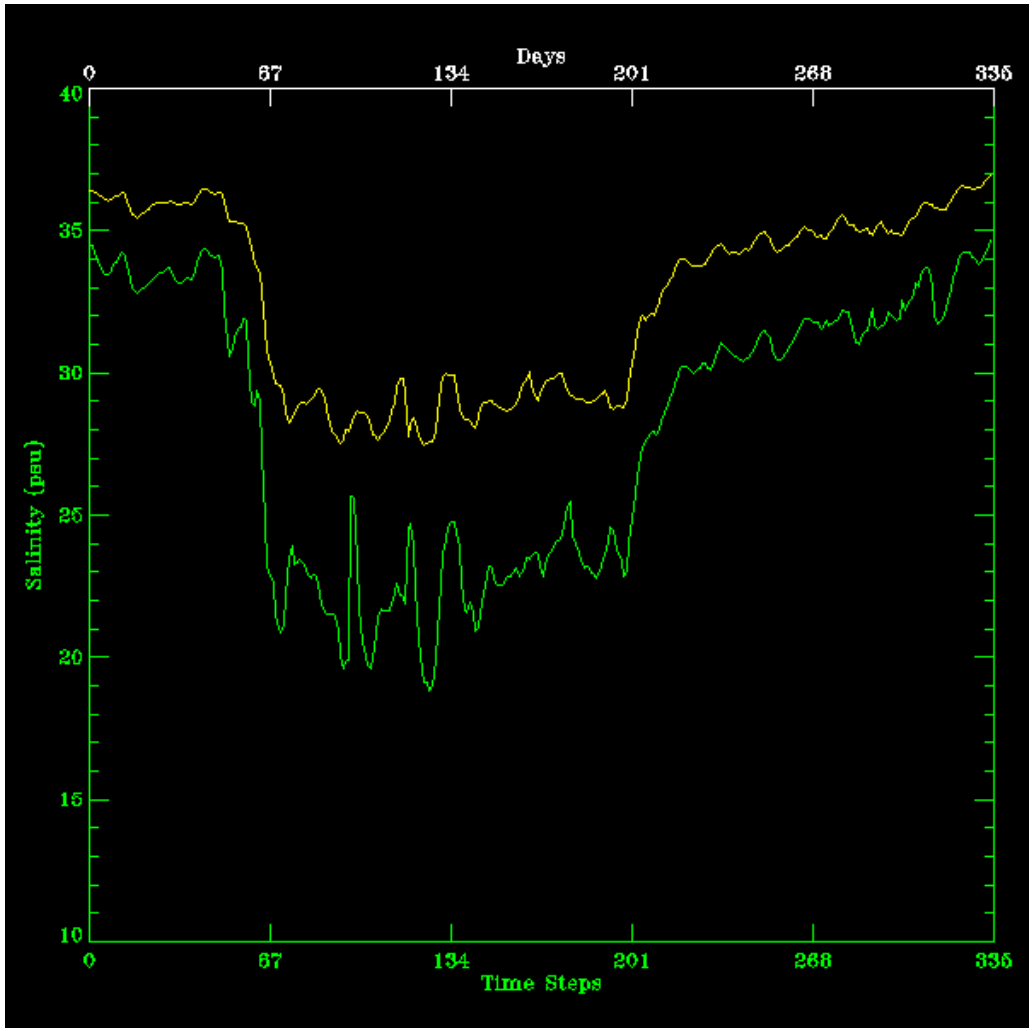


Wedge of lower salinity water in model matches zone of SAV in benthic survey



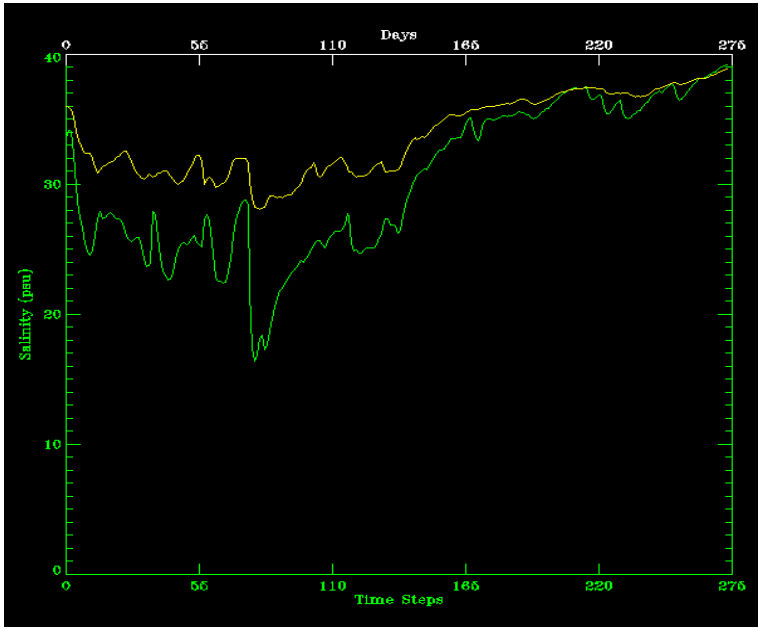
Modeled Results – Slow-ag

Slow_ag



Slow steady flow extended over longer period of time results in sustained reduction in salinity at indicator stations

Base



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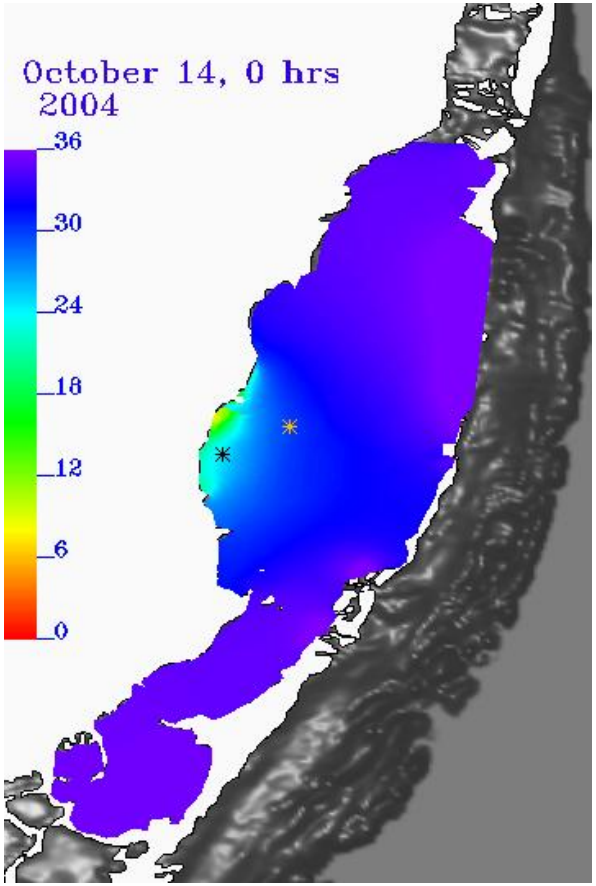
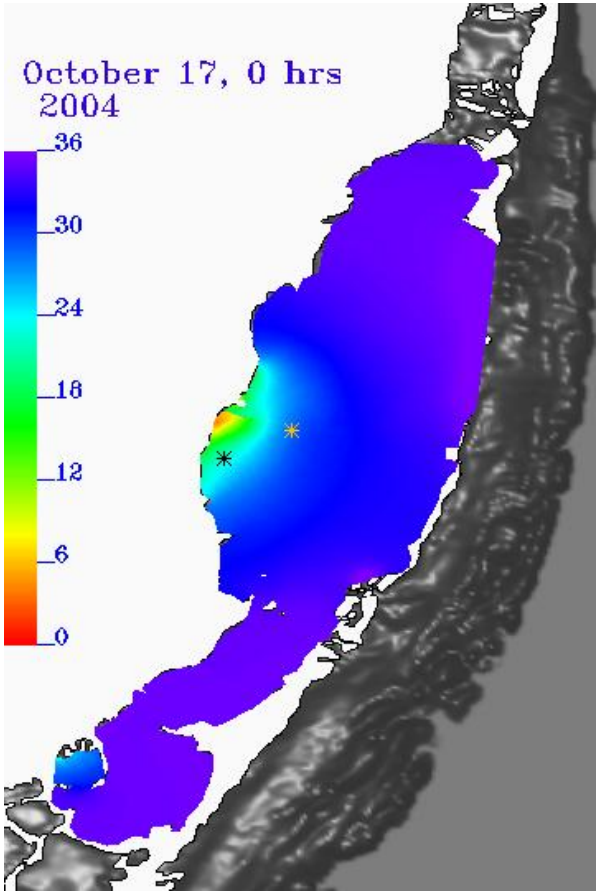
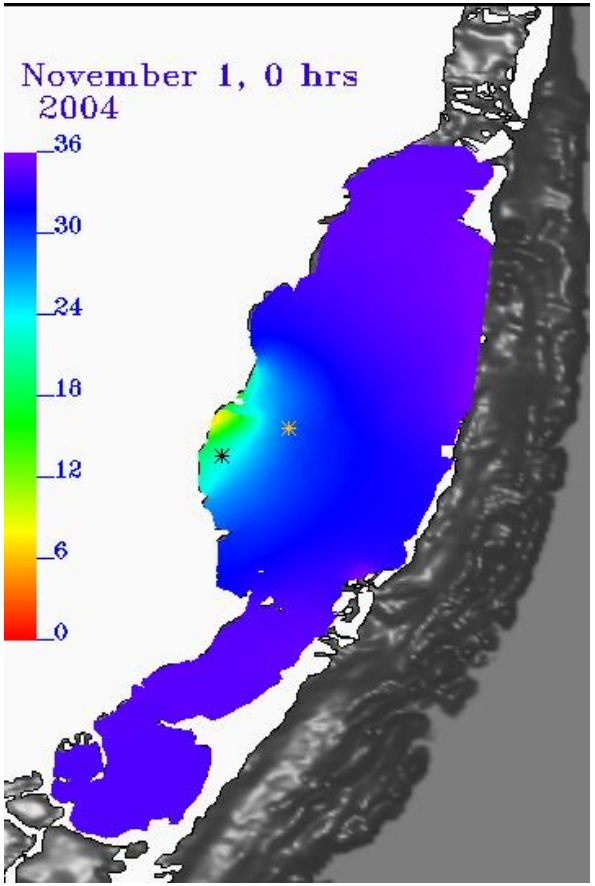
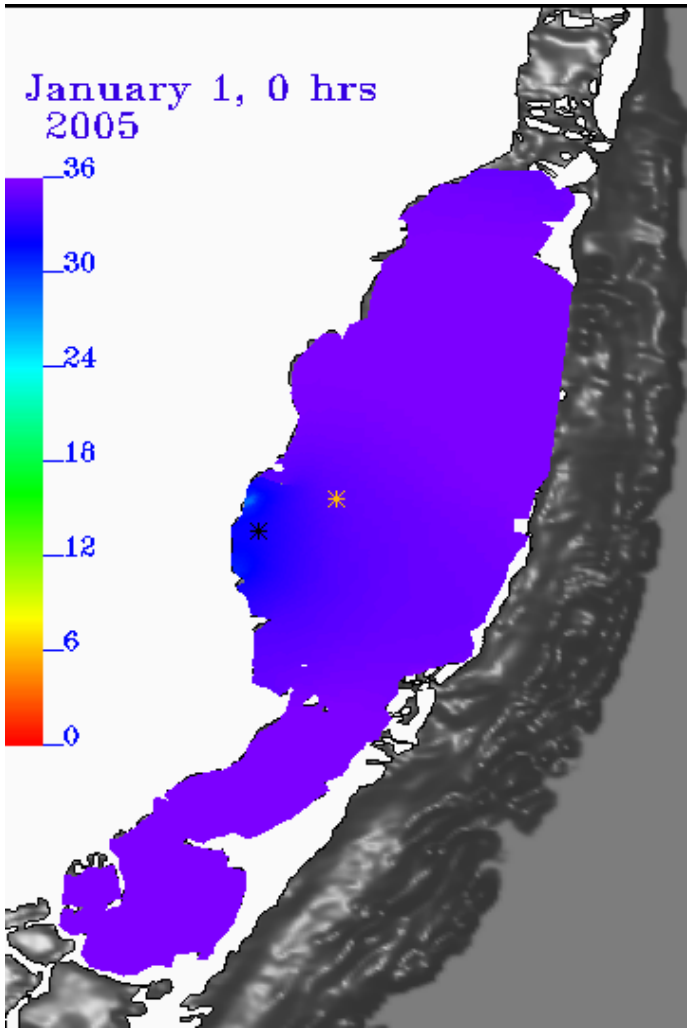
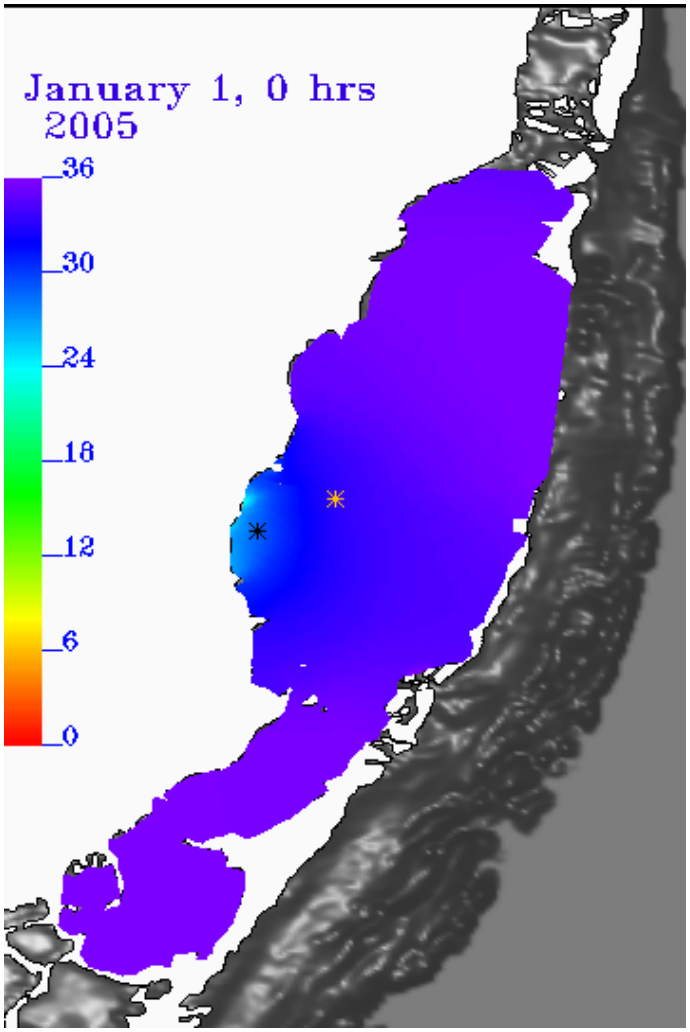




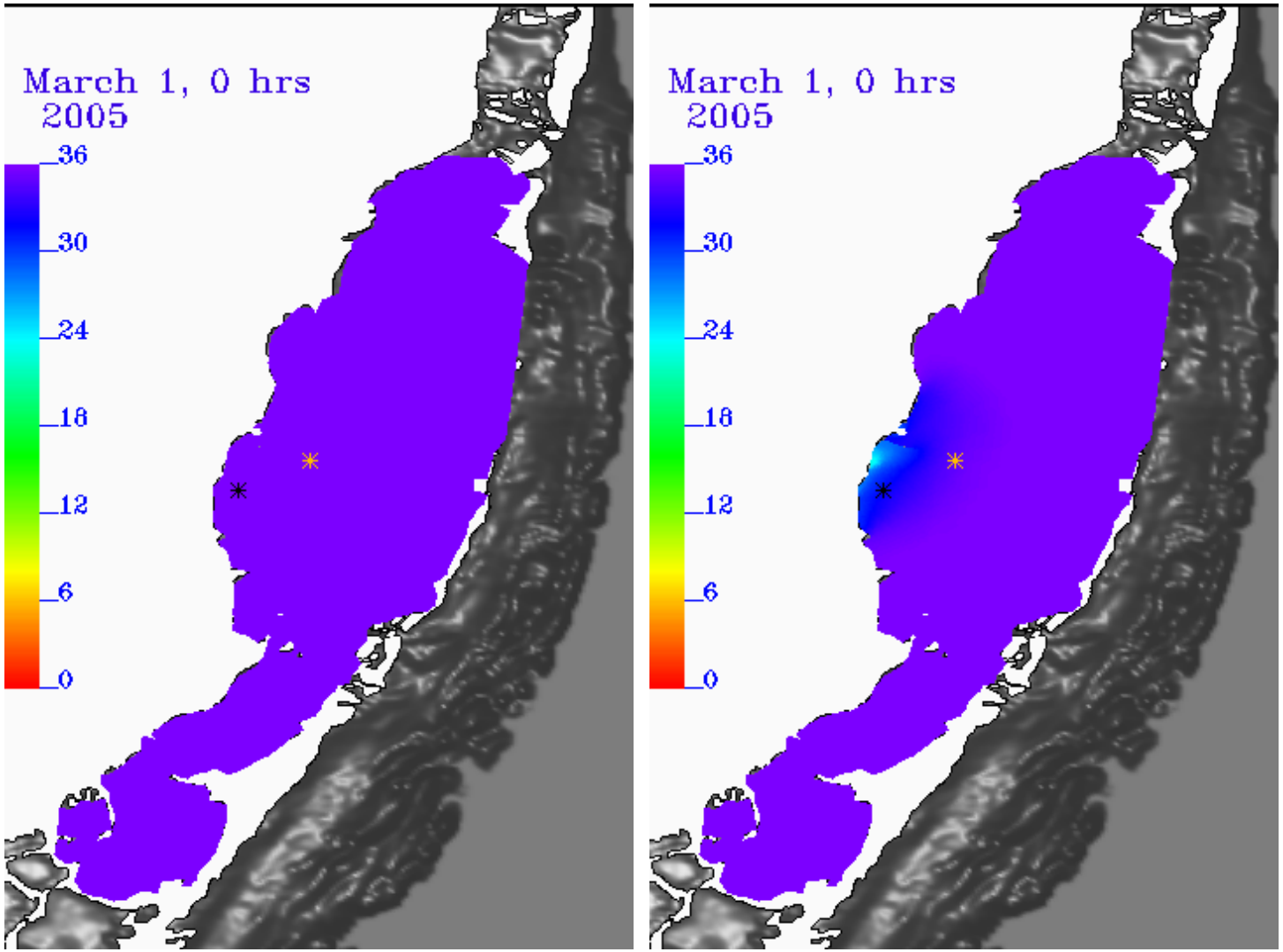


Modeled Results - Base v Slow-ag

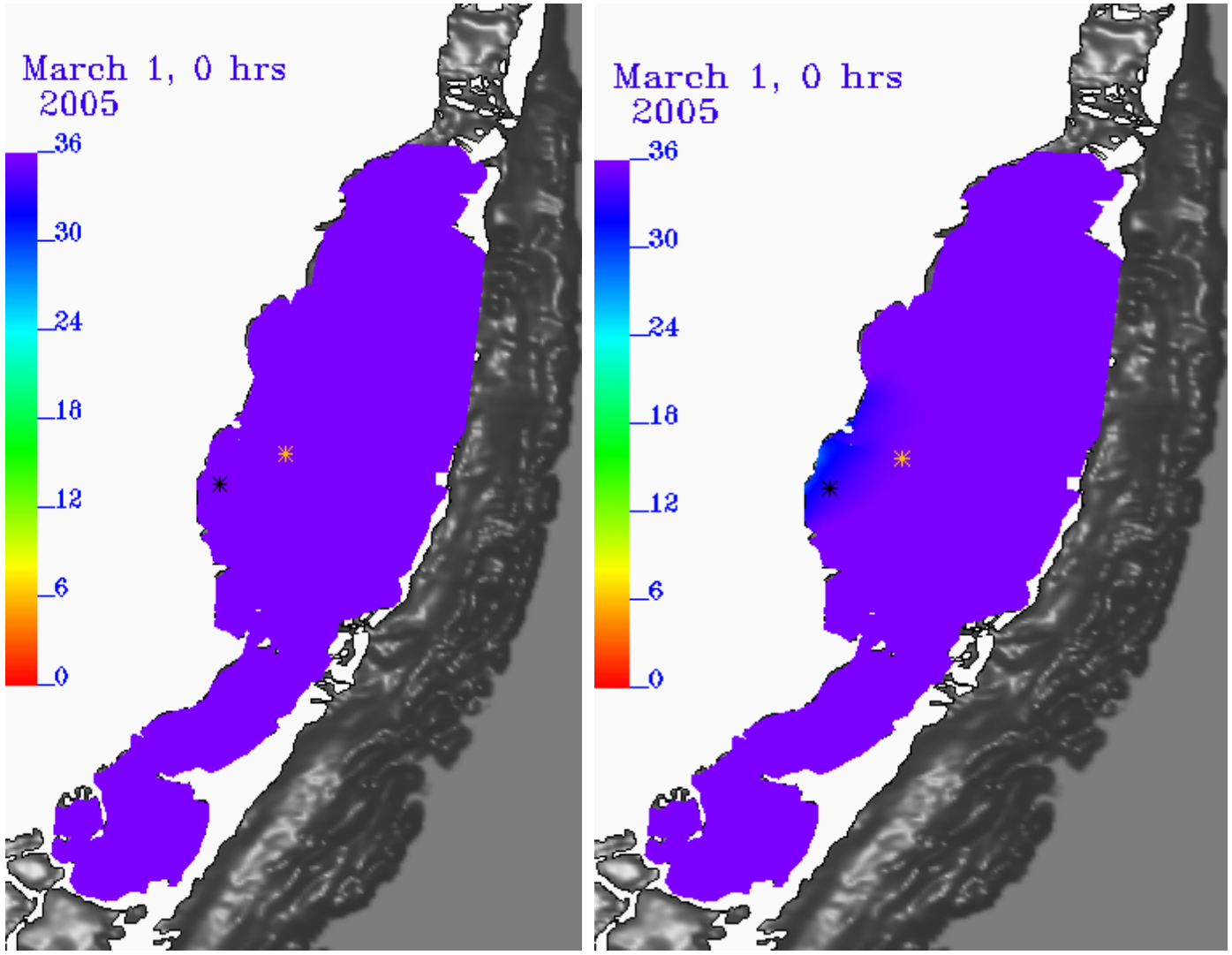




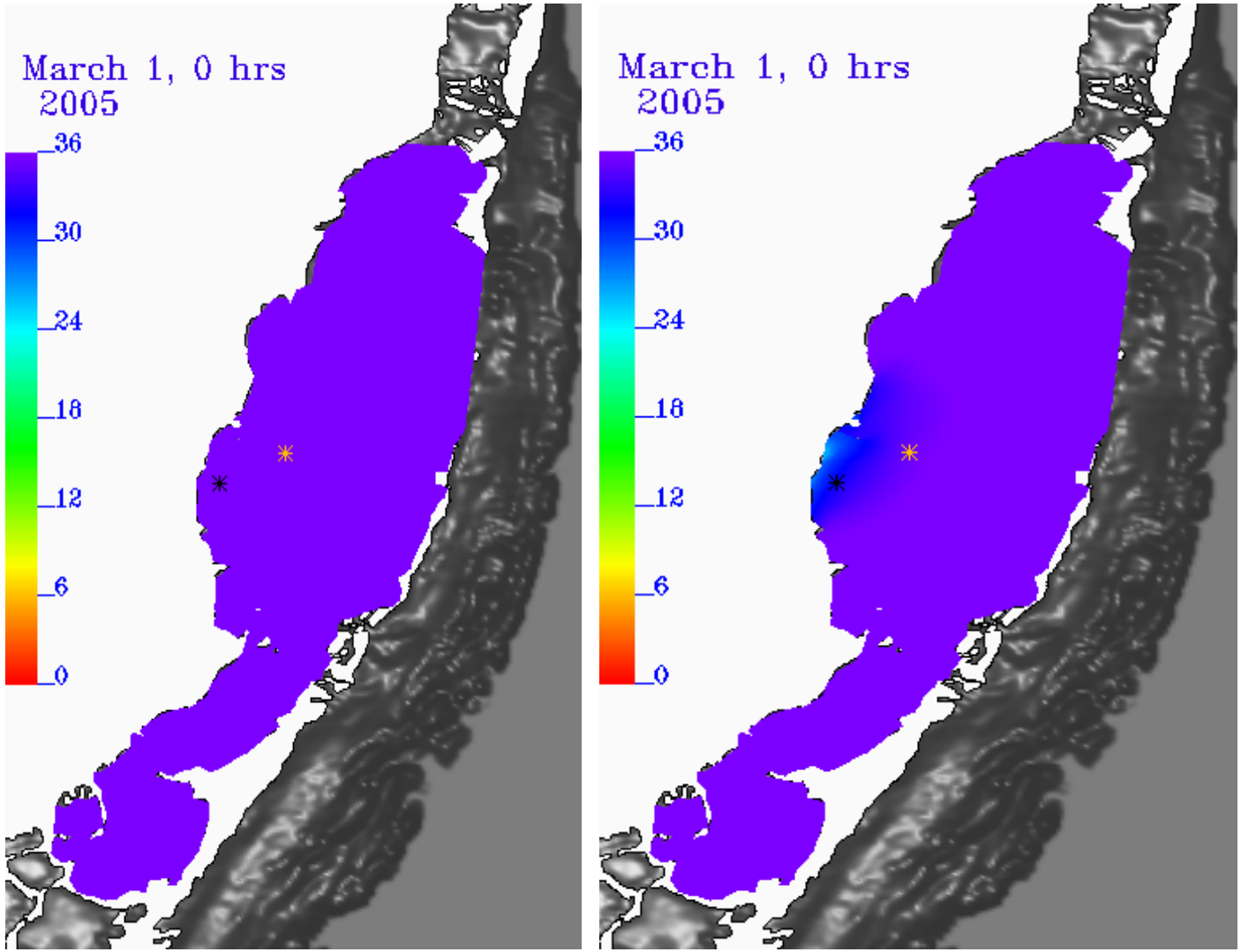
Modeled Results - Base v Slow-ag



Modeled Results – Base v culverts–ag



Modeled Results – Base v redist–ag



Next steps

- Improved model viewer and post-processing (active project)
- Investigate current BBCW Phase 1 plan and match modeled culvert locations to reality
- Improve estimate of water needed to reach targets**
  - 10 k acre mesohaline condition in western Biscayne Bay
  - Coastal mangrove zone salinity 0 – 5 wet season, <20 annual ave.
  - Natural timing and distribution

**SFNRC, 2006, *Ecological & Hydrologic Targets for Western Biscayne National Park*. South Florida Natural Resources Center, Everglades National Park, Homestead, FL. SFNRC Technical Series 2006:1.25 pp.

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