About ADMi

- Advanced Data Mining International, LLC
  - Greenville, SC; founded 2002
  - Clients – Alcoa, BP, B&V, state agencies, water utilities, USACOE, USGS, USDOE, WERF, WRF…………..
- Focus
  - Problem solving through data mining
  - Solutions deployed with Decision Support Systems (DSS)
- Expertise
  - Industrial – polymers, metals, oil & gas
  - Water – treatment optimization, DBPs, event detection systems (EDS)
  - Natural Systems – surface & ground water modeling for resource management, TMDLs
    - Projects in FL, GA, OR, SC, WI

Estimating Salinity Effects Due to Climate Change on the Georgia and South Carolina Coasts

Water Research Foundation (WRF) Project 4285

Beaufort-Jasper Water and Sewer Authority (BJWSA)

ADMi

U.S. Geological Survey (USGS)

University of South Carolina (USC)

South Carolina Sea Grant Consortium (Sea Grant)

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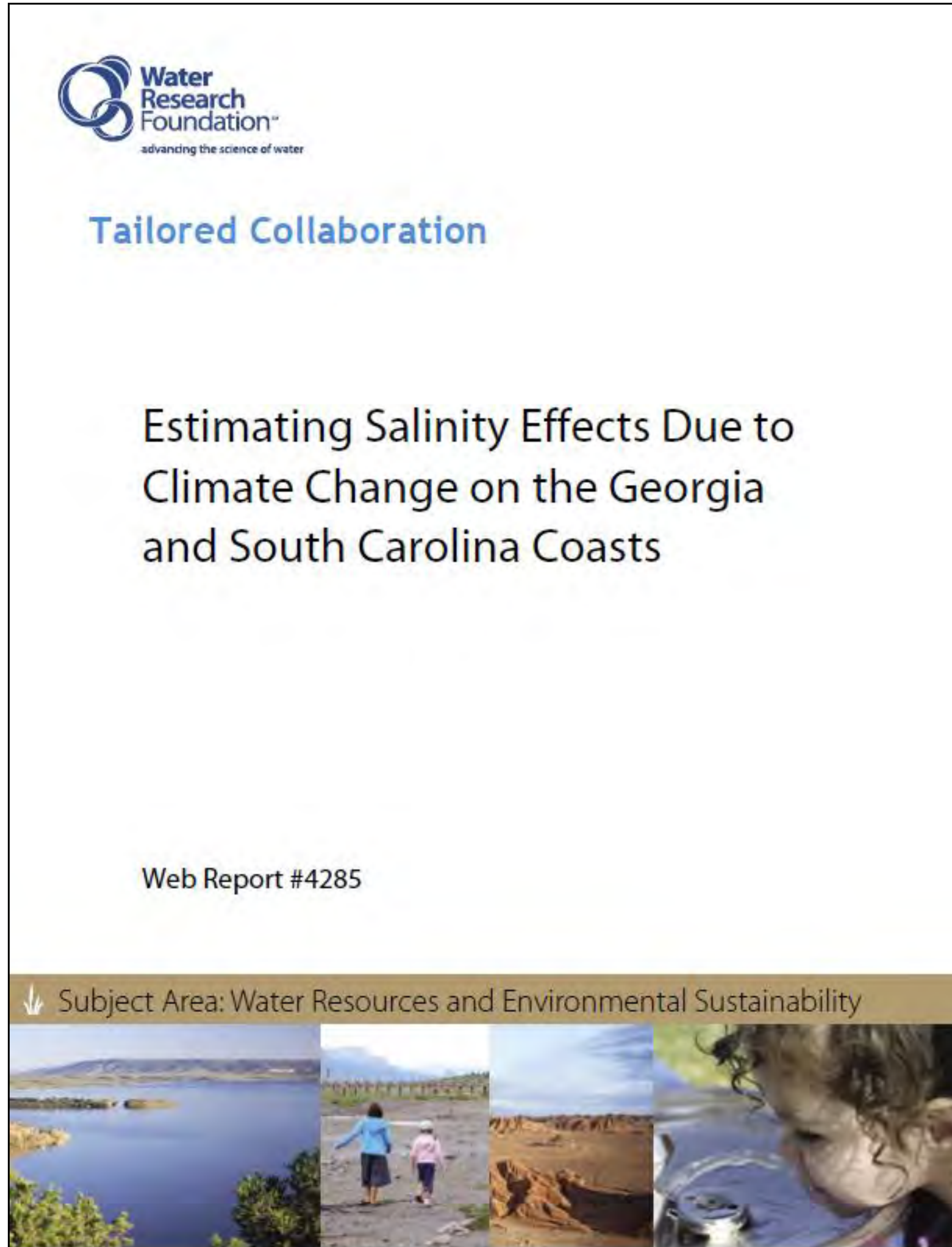
- Published Sept. 2012
- Shortened version of full USGS report to come
- Written for utility personnel
- Even shorter white paper is available


Water Research Foundation
advancing the science of water

Tailored Collaboration

Estimating Salinity Effects Due to Climate Change on the Georgia and South Carolina Coasts

Web Report #4285

Subject Area: Water Resources and Environmental Sustainability

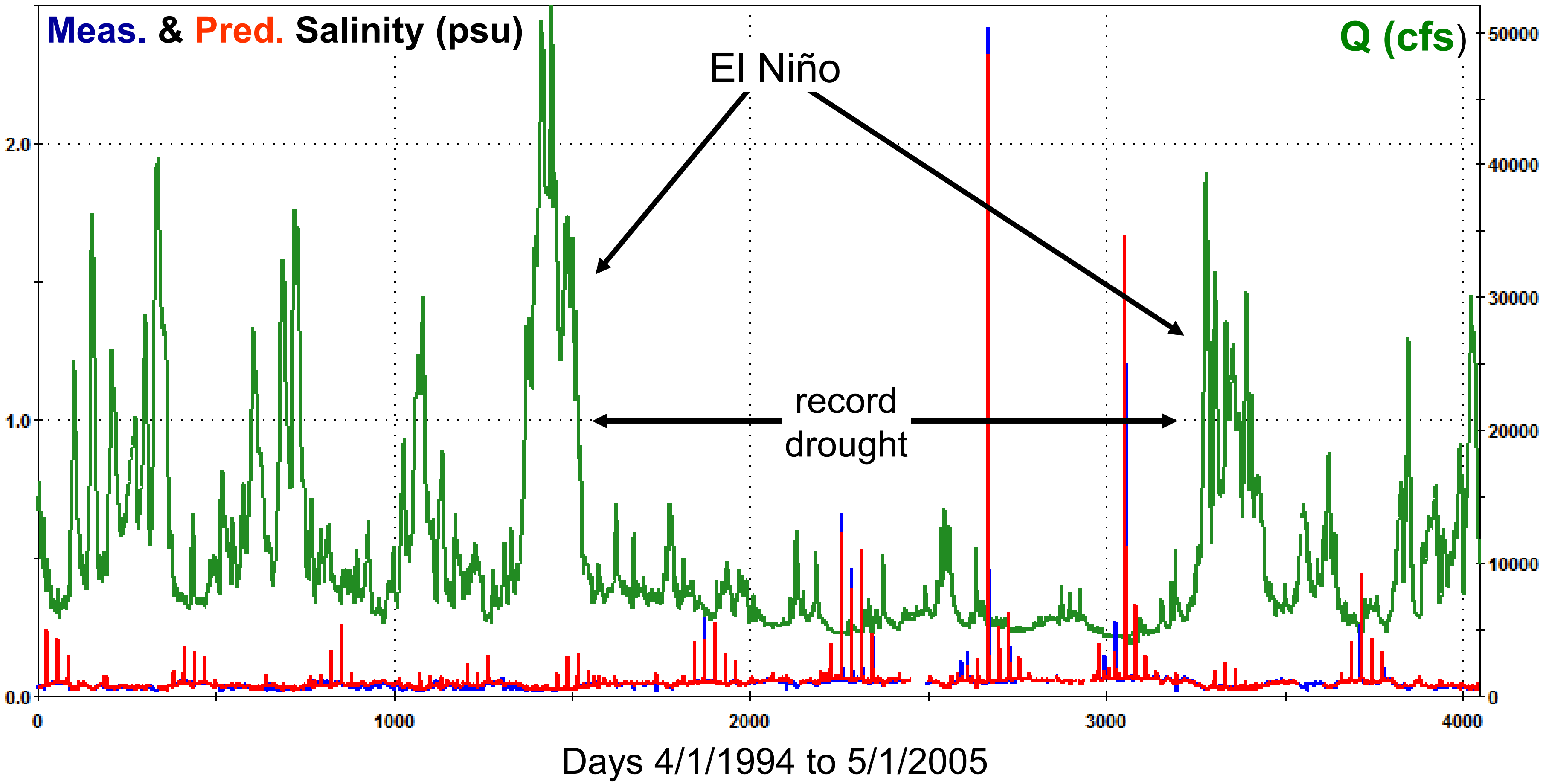
Utilities with intakes at risk from climate change & sea-level rise (SLR)

Source: modified from Furlow et al. 2002

Project goal and thesis

- Goal - develop practical method for utilities to assess vulnerability to climate change and SLR
- Thesis
  - Because of past storms and droughts, long-term historical data already contains the information about how a hydrologic system will respond
  - Accurate models for the full range of historical forcing can be used to asses risk.

Droughts, El Niño, intrusion events (Savannah River Estuary)



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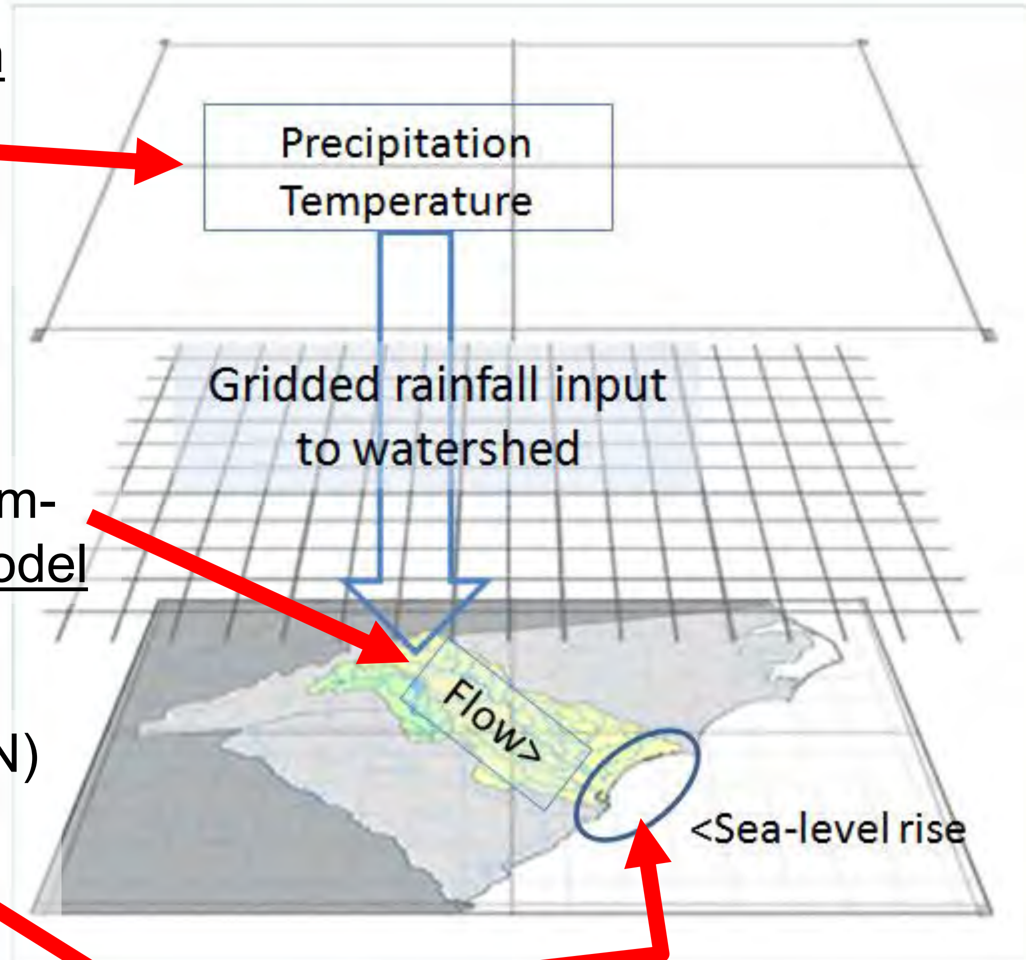
Technical Approach

Integrate 3 models

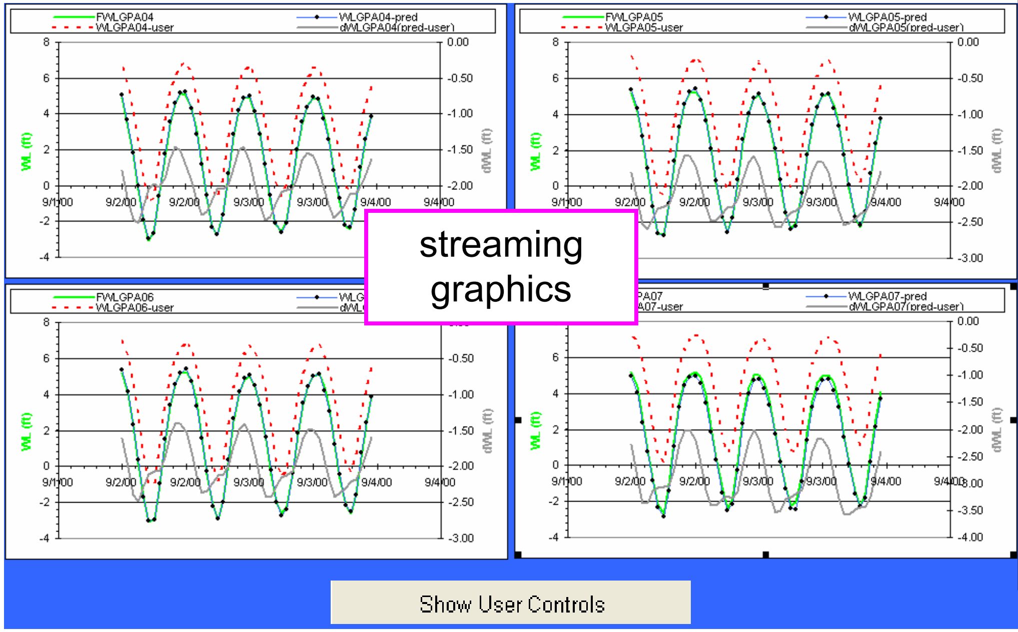
ECHO-G global circulation model (GCM) with A2 future carbon emissions scenario

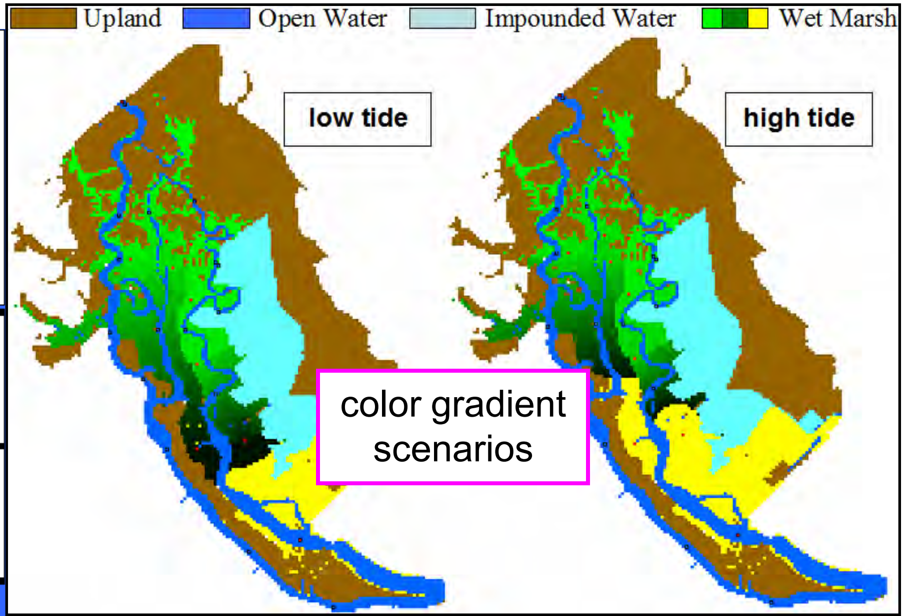
Hydrologic Simulation Program-Fortran (HSPF) watershed model

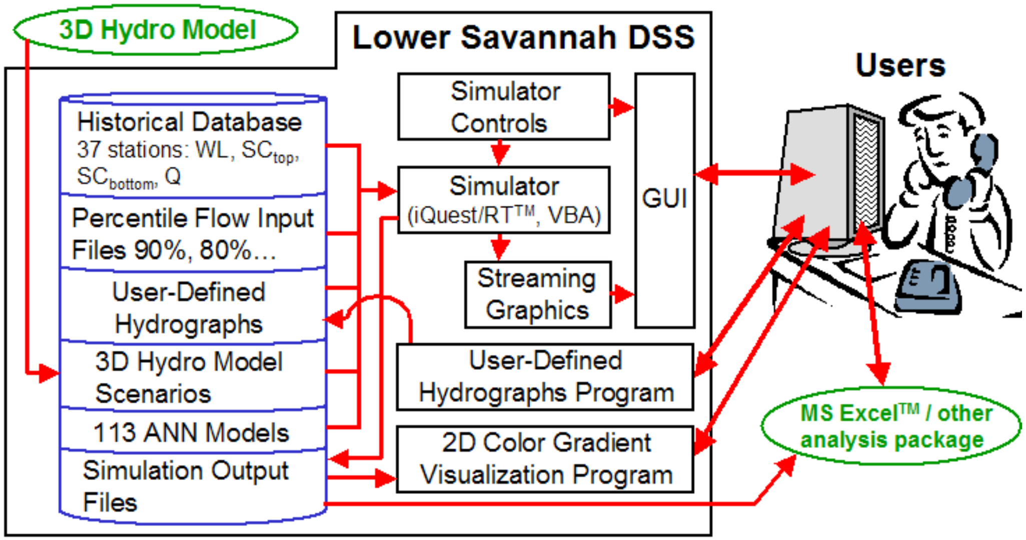
Artificial Neural Network (ANN) estuary model embedded in decision support systems (DSS)

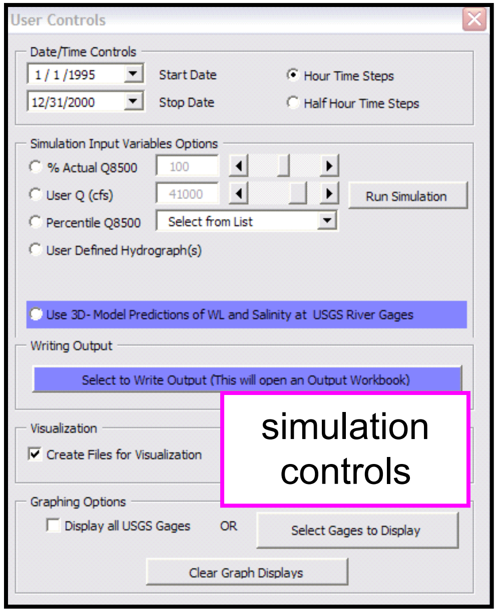


Decision support systems (DSS)







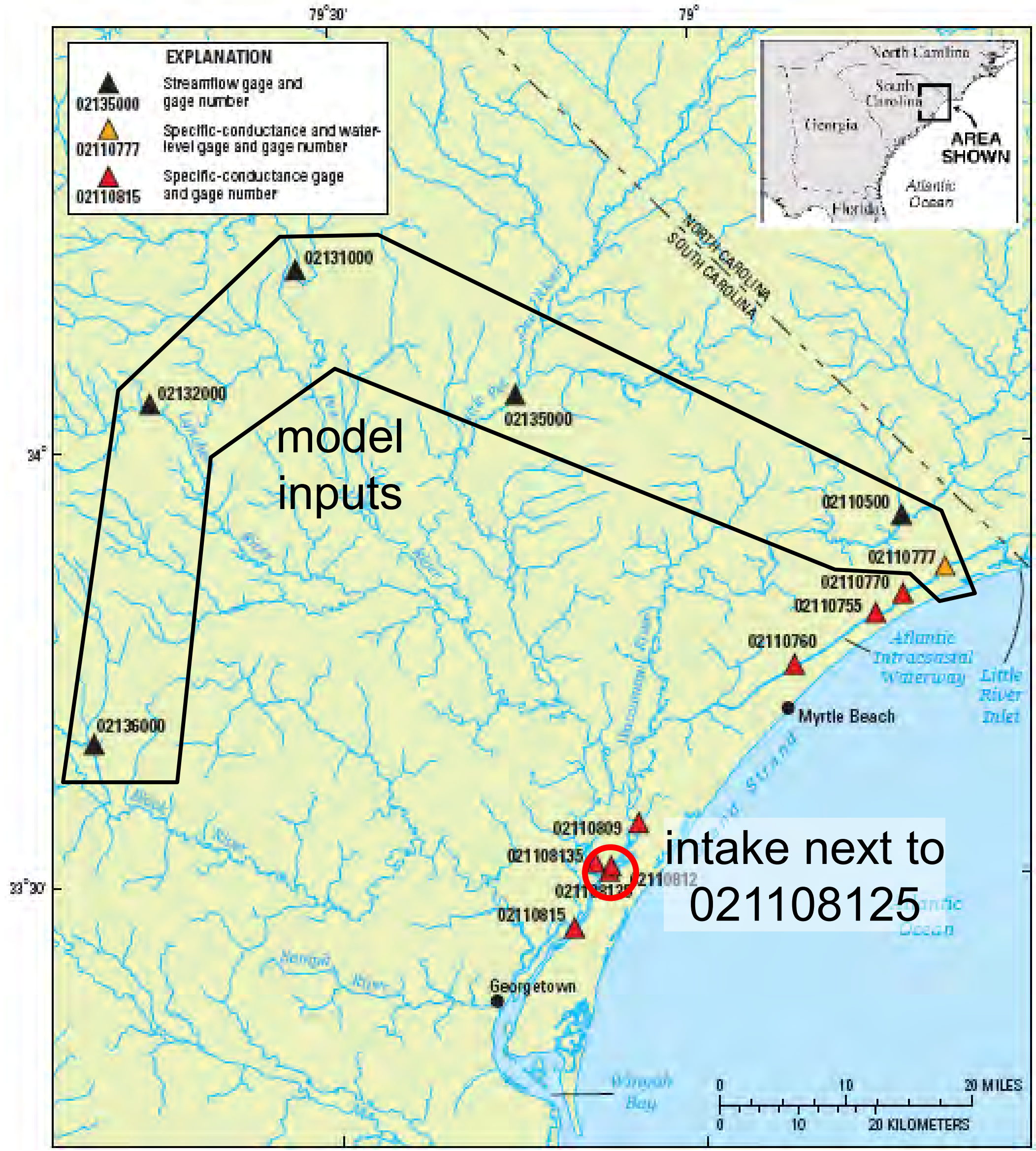


2 example estuaries

- Pee Dee Basin
  - Intake on Waccamaw River
  - Preexisting model - PRISM (2007) for FERC relicensing of dams
  - This project – GCM + watershed model + estuary model DSS
- Lower Savannah River
  - Intakes on Albercorn Creek and Savannah River
  - Preexisting model - M2M (2006) for Savannah Harbor deepening
  - This project – used only estuary model DSS

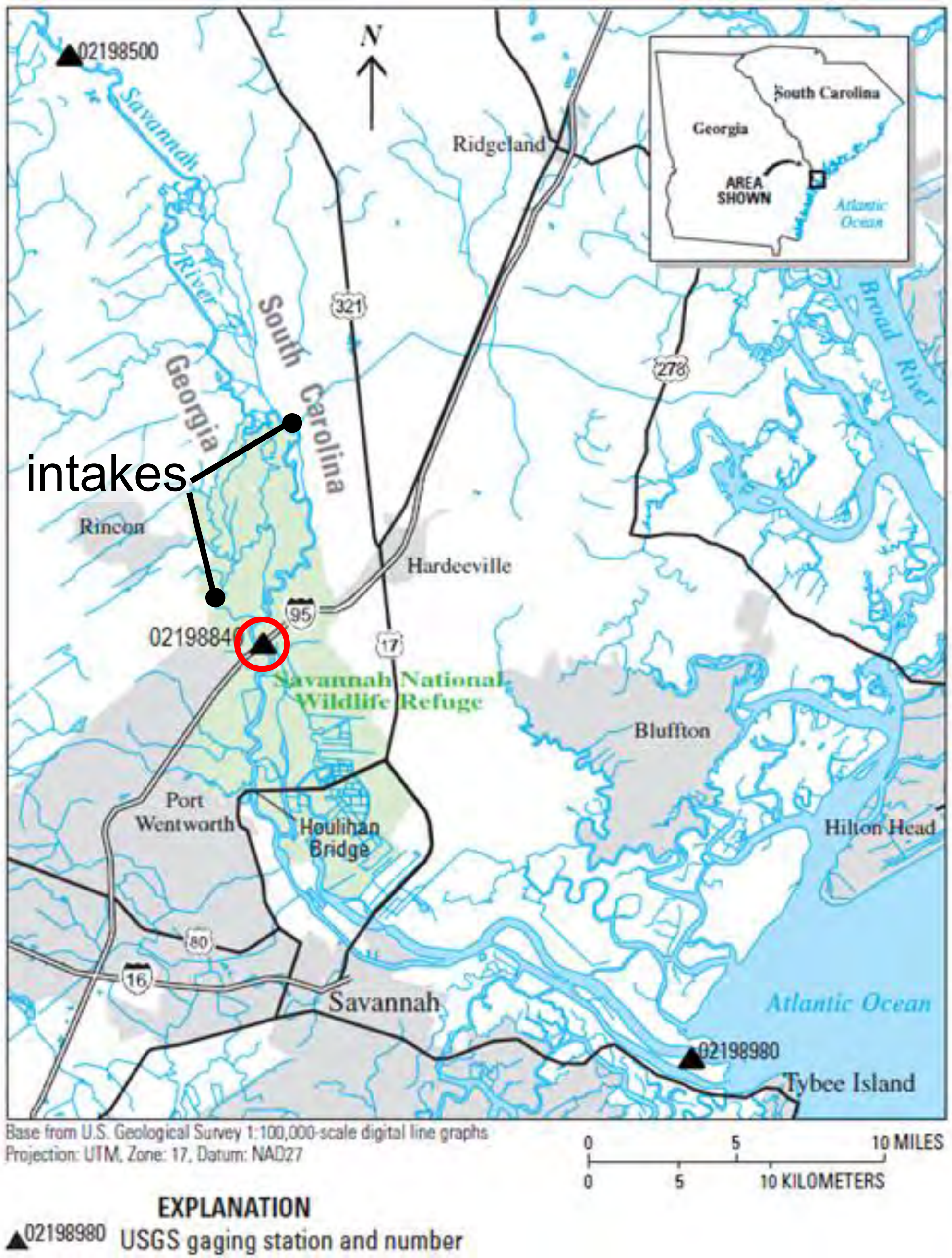
Pee Dee Basin

- PRISM DSS (**P**ee Dee **R**iver and Atlantic **I**ntracoastal Waterway **S**alinity Intrusion **M**odel)
- FERC relicensing of NC dams
- Calibrated 1995-2009
  - added new data for this project



Lower Savannah River

- M2M DSS (Model to Marsh)
- Modeled impacts of harbor deepening on SNWR
- Connects EFDC to UFL's "Plant Succession Model"
- Calibrated 1994-2005



Roles of participants

- WRF & BJWSA - sponsors
- USGS – originated idea, tech team coordination, climate change modeling
- USC* – downscaling model to Pee Dee River basin, outreach workshops with DSSs to Grand Strand and Savannah stakeholders
- ADMi+ – developed estuary models and DSSs
- SC Sea Grant* – outreach workshops

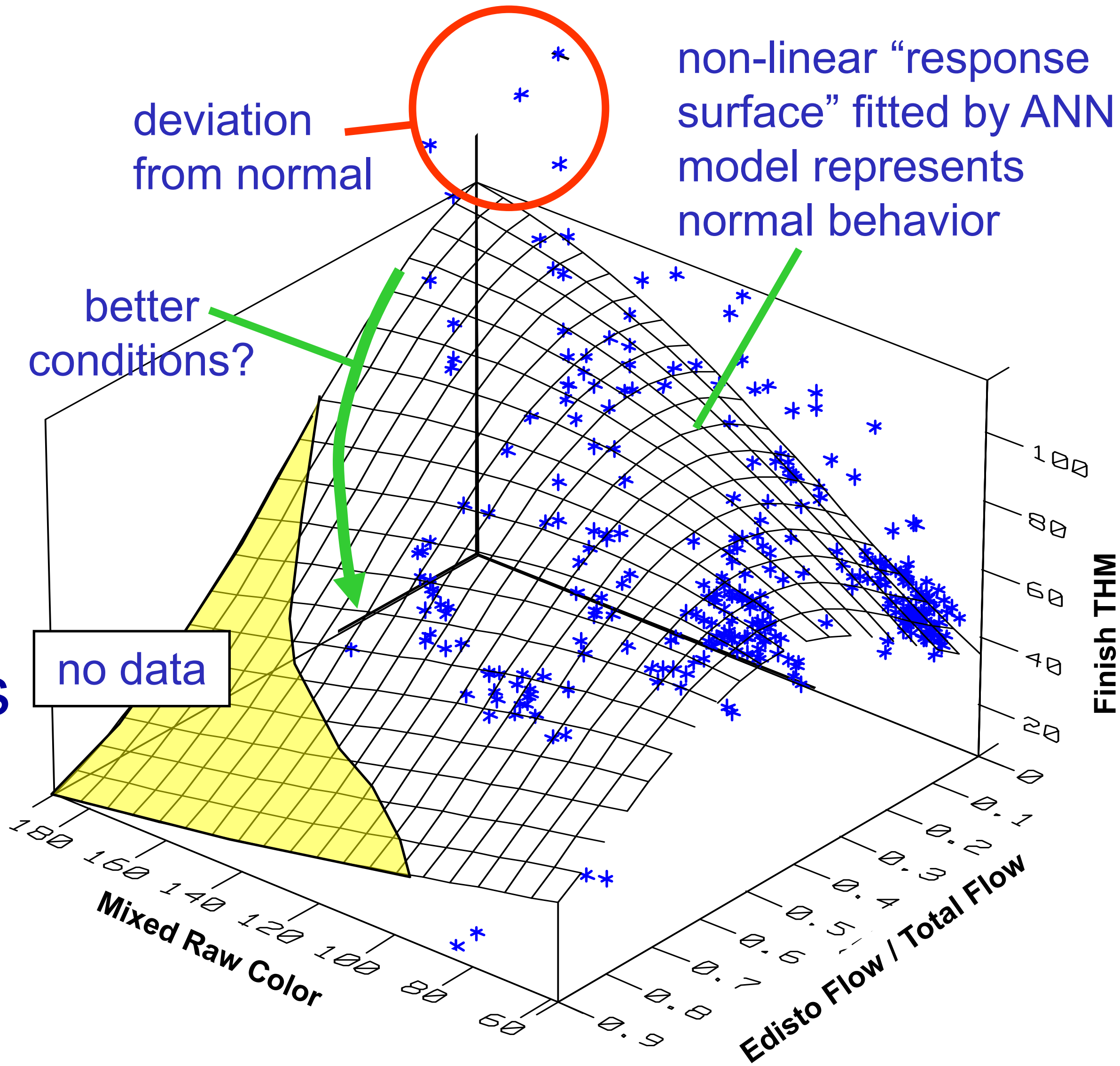
* funded by NOAA

+ co-funded by WRF & NOAA

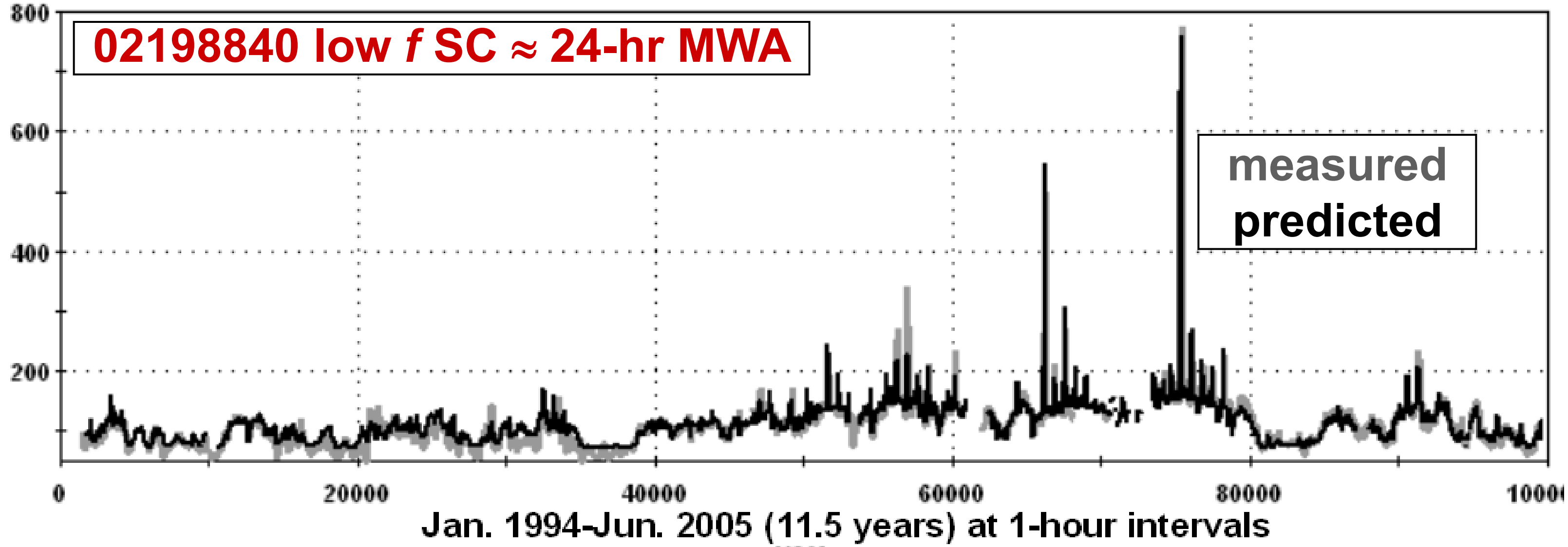
About ANN Modeling

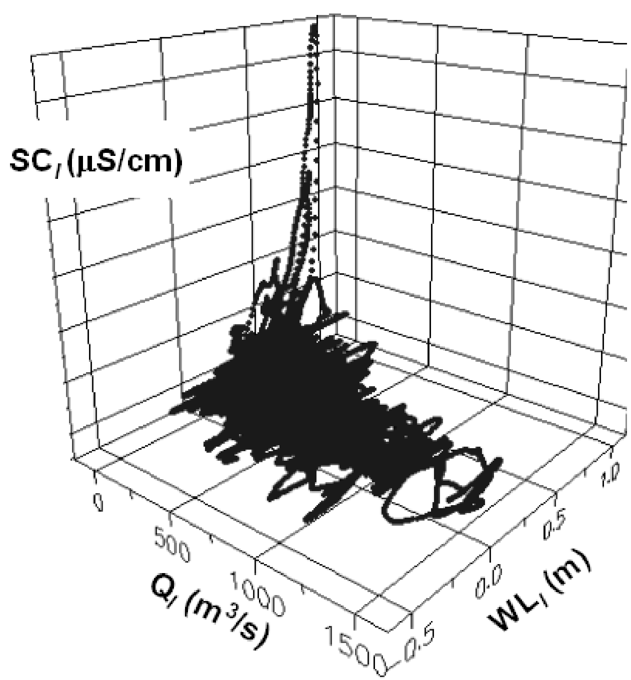
Process modeling with artificial neural networks (ANN)

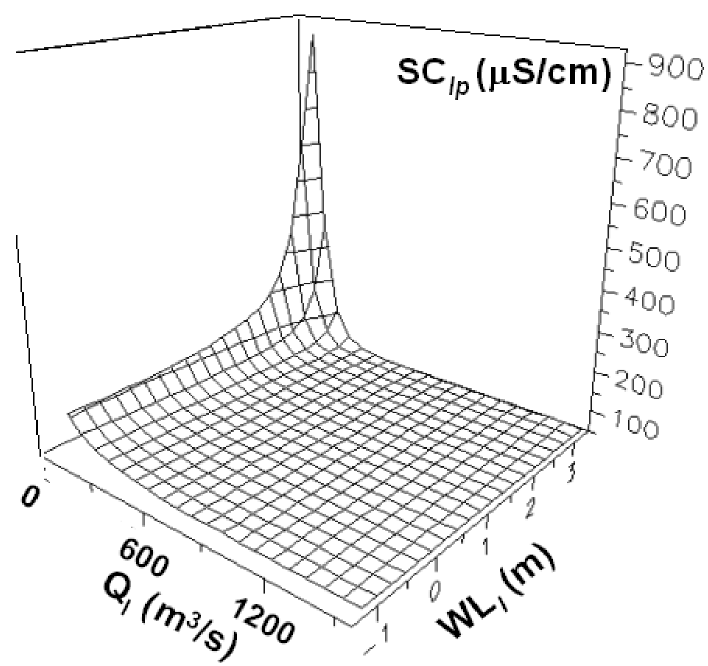
- Multivariate curve fitting
- Fits are “learned”, not prescribed like least-squares
- Used in continuous process industries



M2M – salinity intrusion







Model Calibration

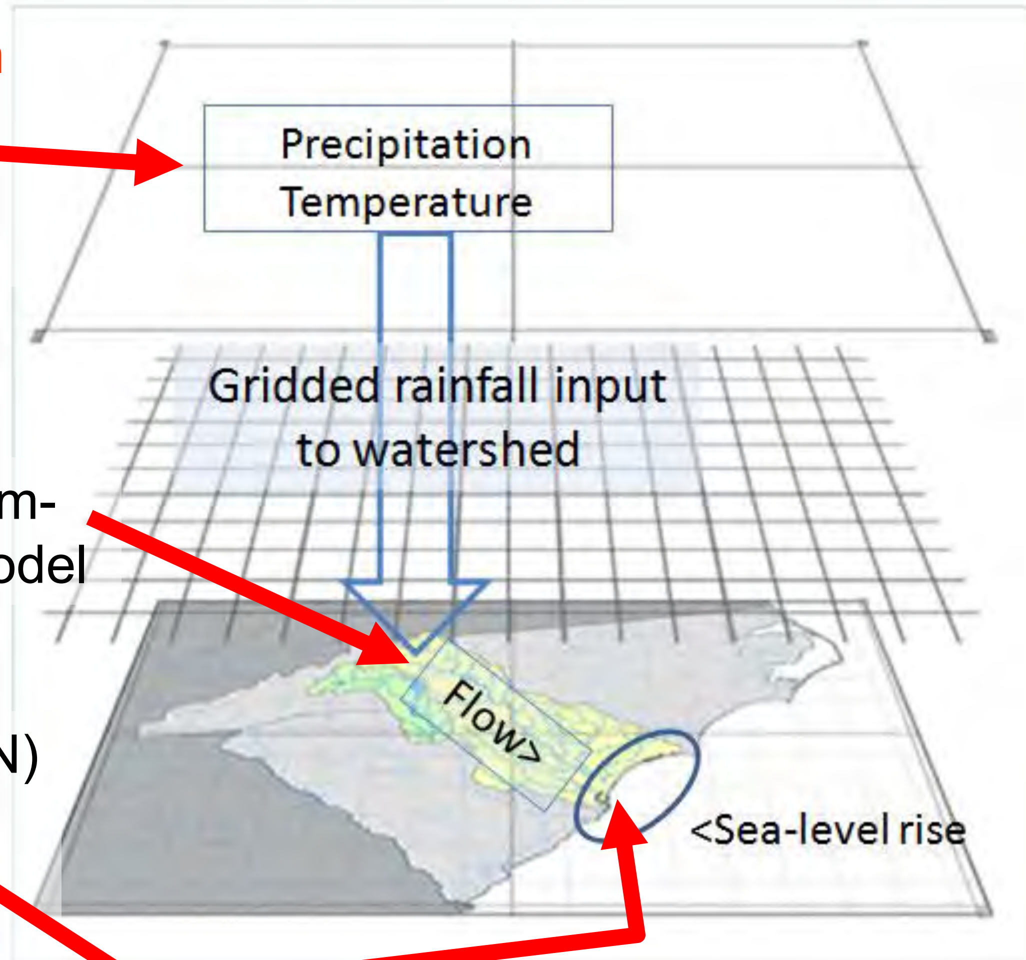
ADMi ADVANCED DATA MINING INTERNATIONAL, LLC

Evaluated 4 GCMs (with calibrated HSPF)

ECHO-G global circulation model (GCM) with A2 future carbon emissions scenario

Hydrologic Simulation Program-Fortran (HSPF) watershed model

Artificial Neural Network (ANN) estuary models embedded in decision support systems (DSS)



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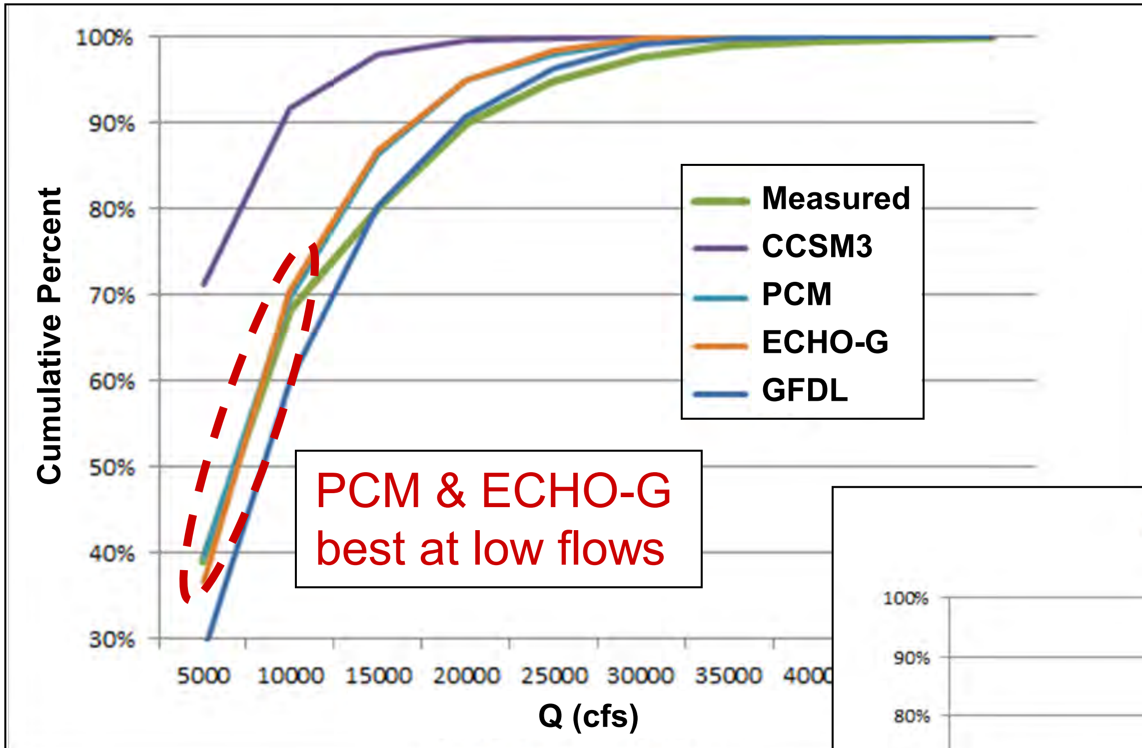
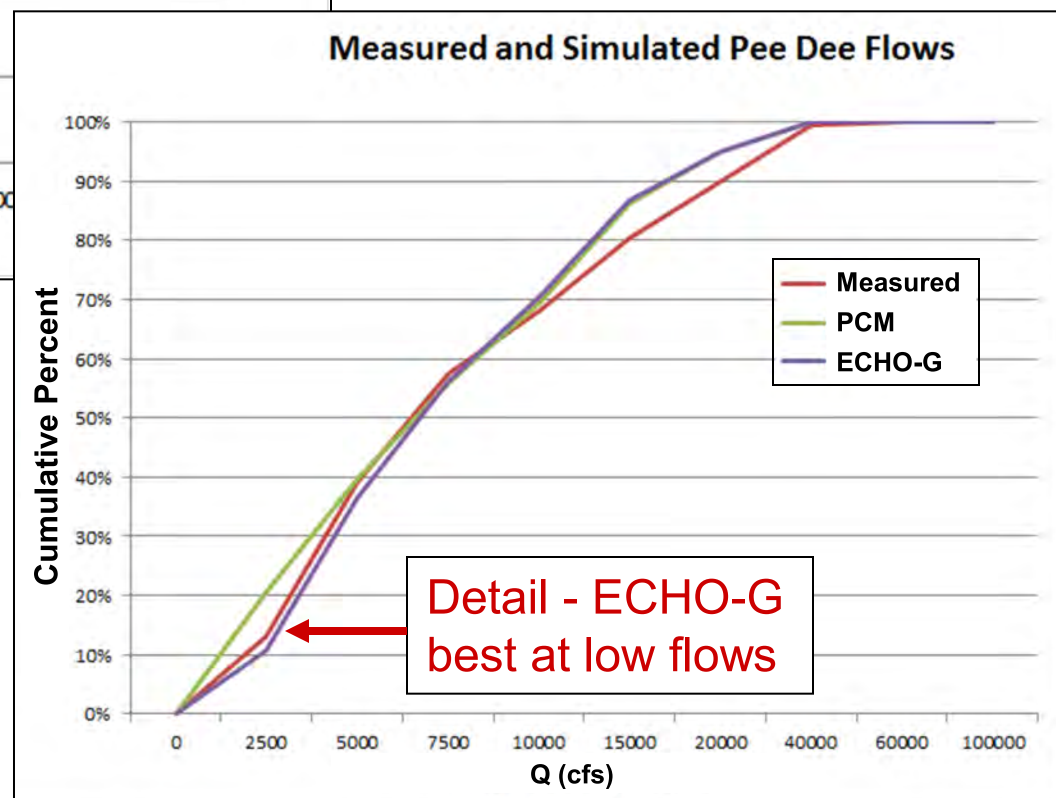
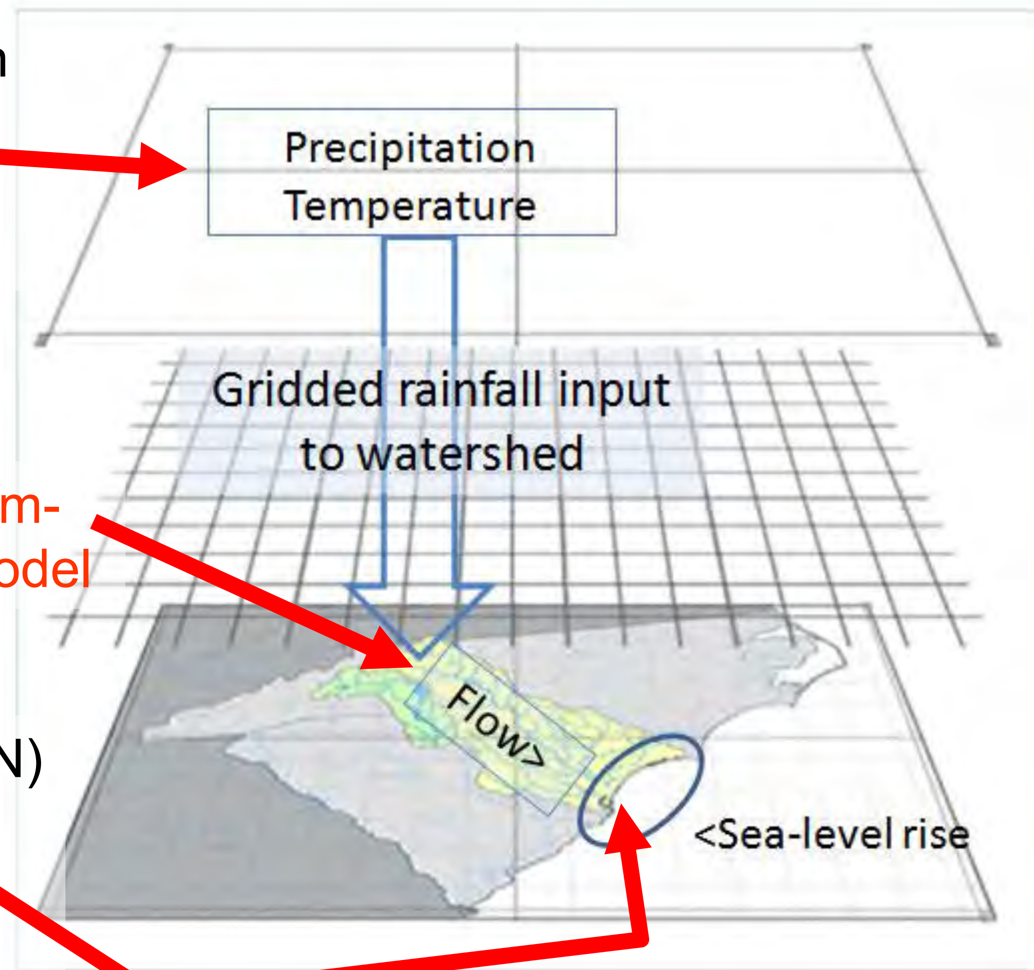
GCM selection





HSPF Calibration

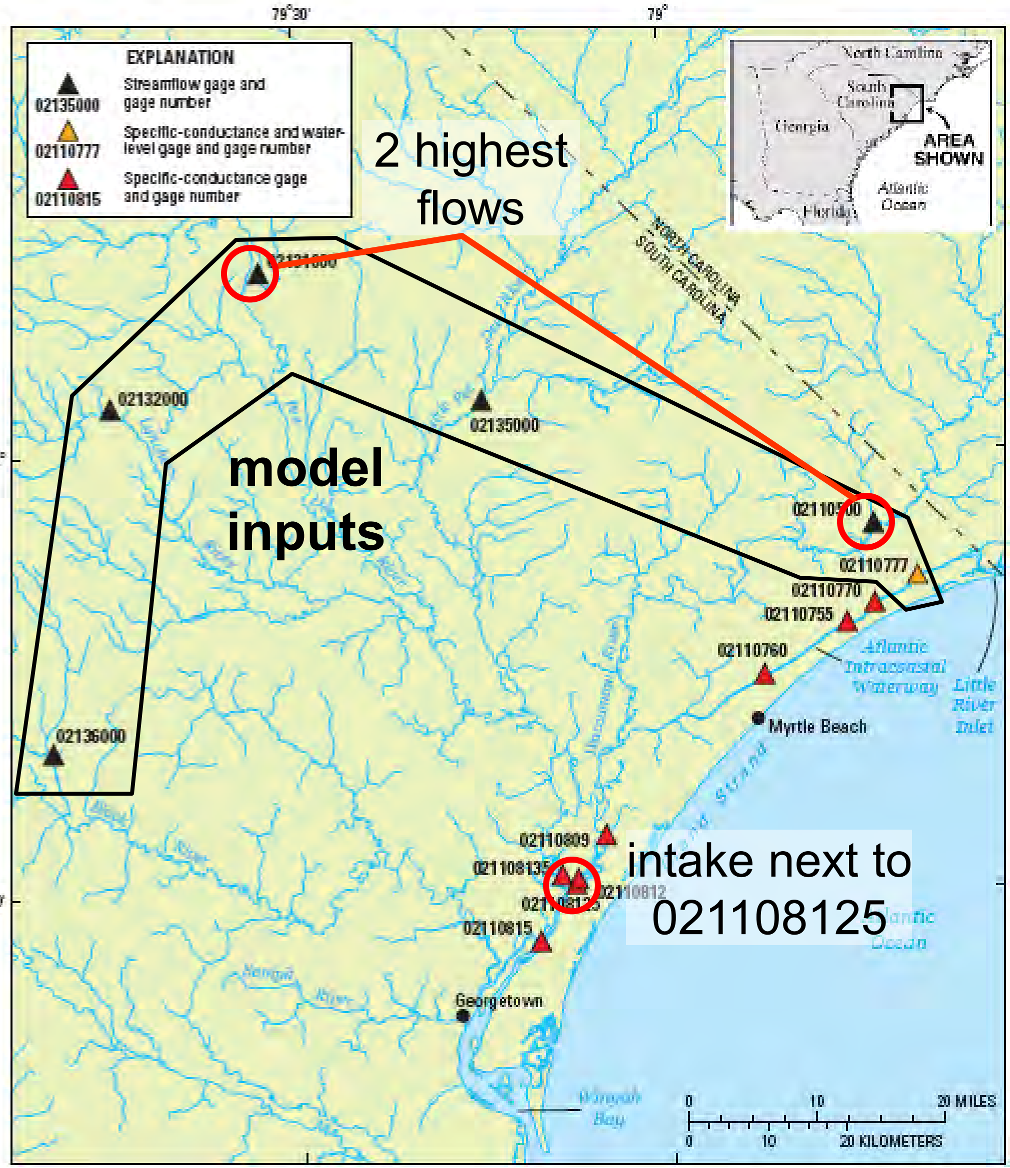
ECHO-G global circulation model (GCM) with A2 future carbon emissions scenario



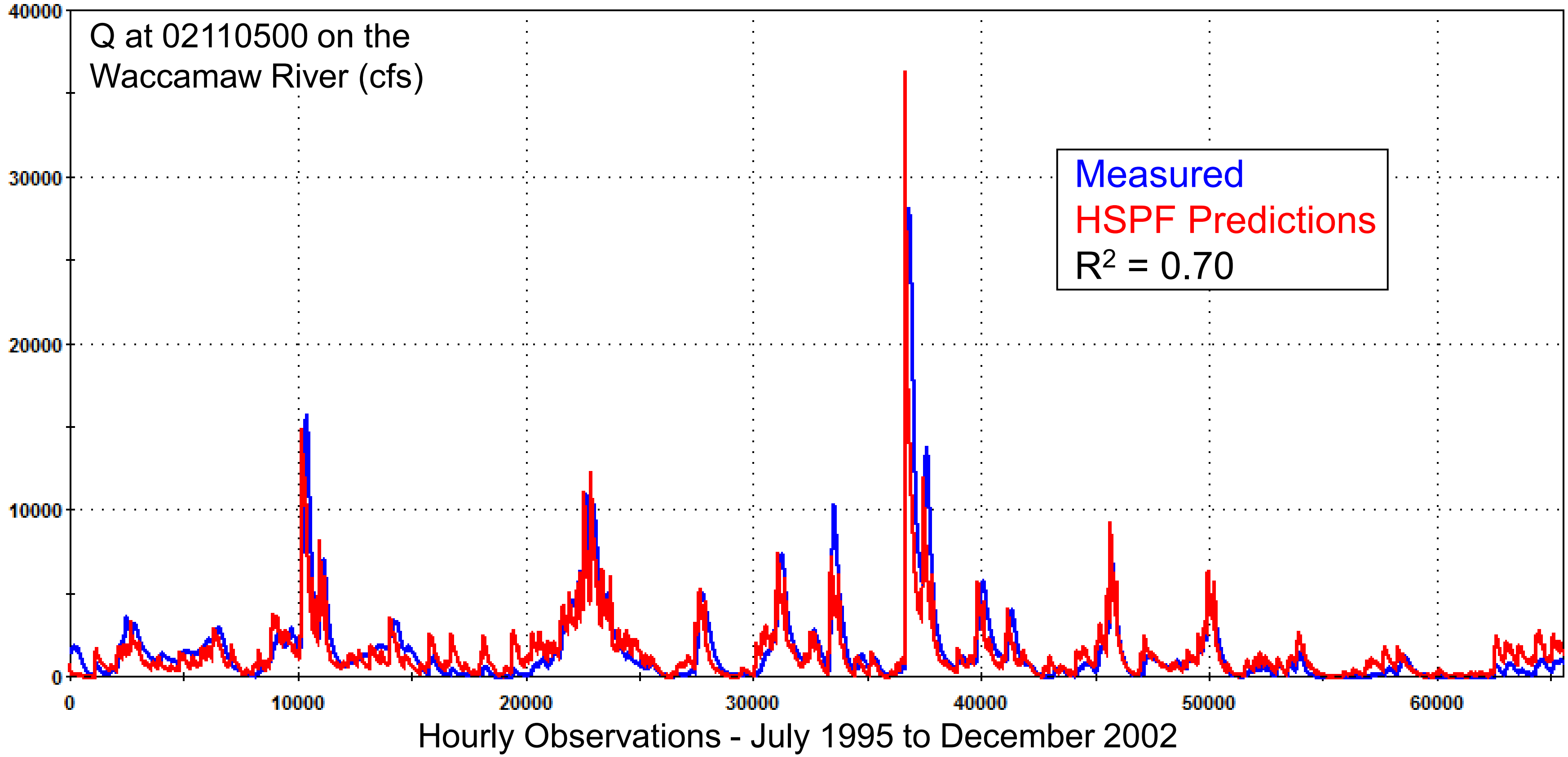
Hydrologic Simulation Program-Fortran (HSPF) watershed model

Artificial Neural Network (ANN) estuary models embedded in decision support systems (DSS)

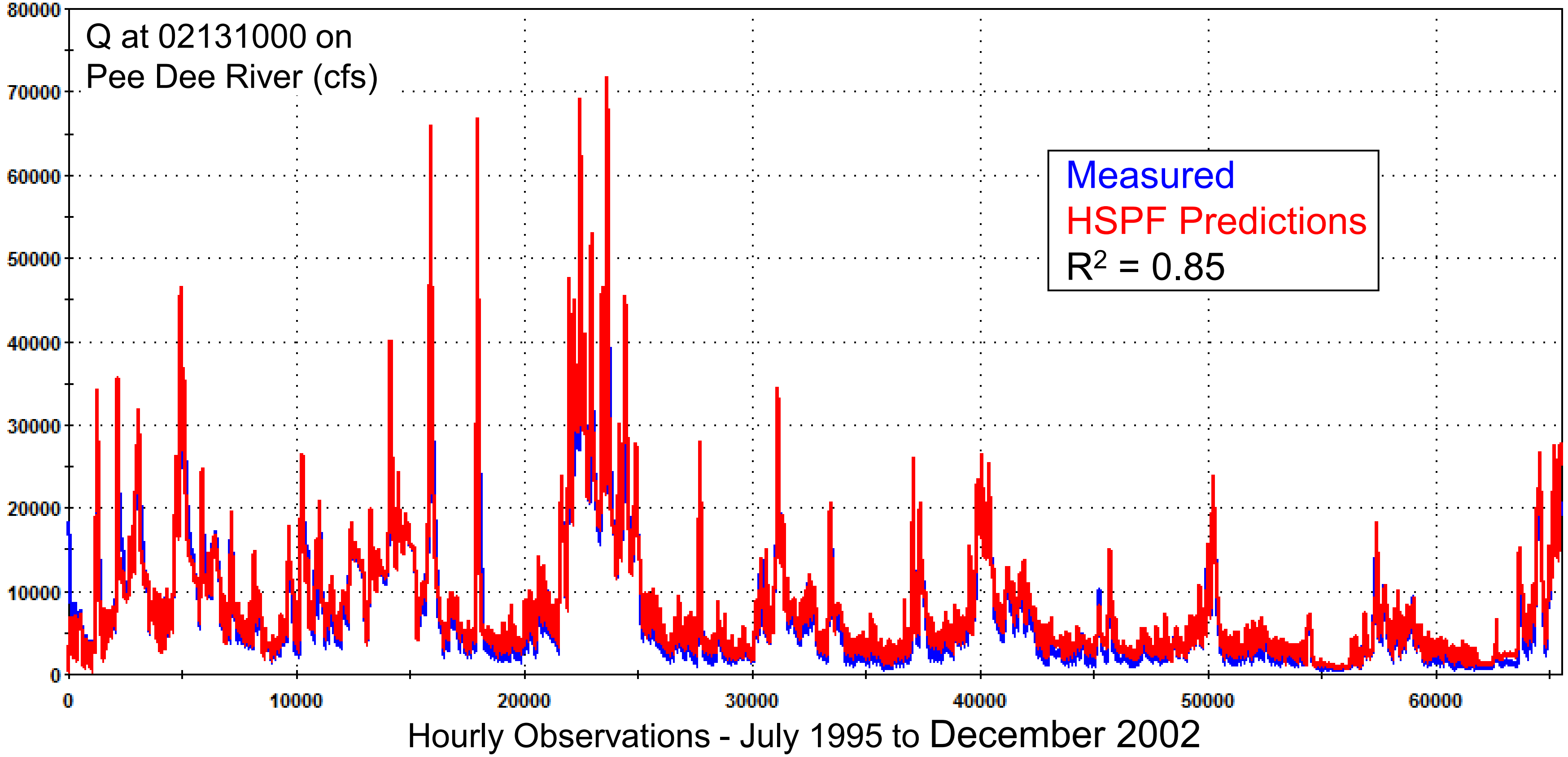
PRISM inputs



HSPF Calibration



cont. - HSPF Calibration

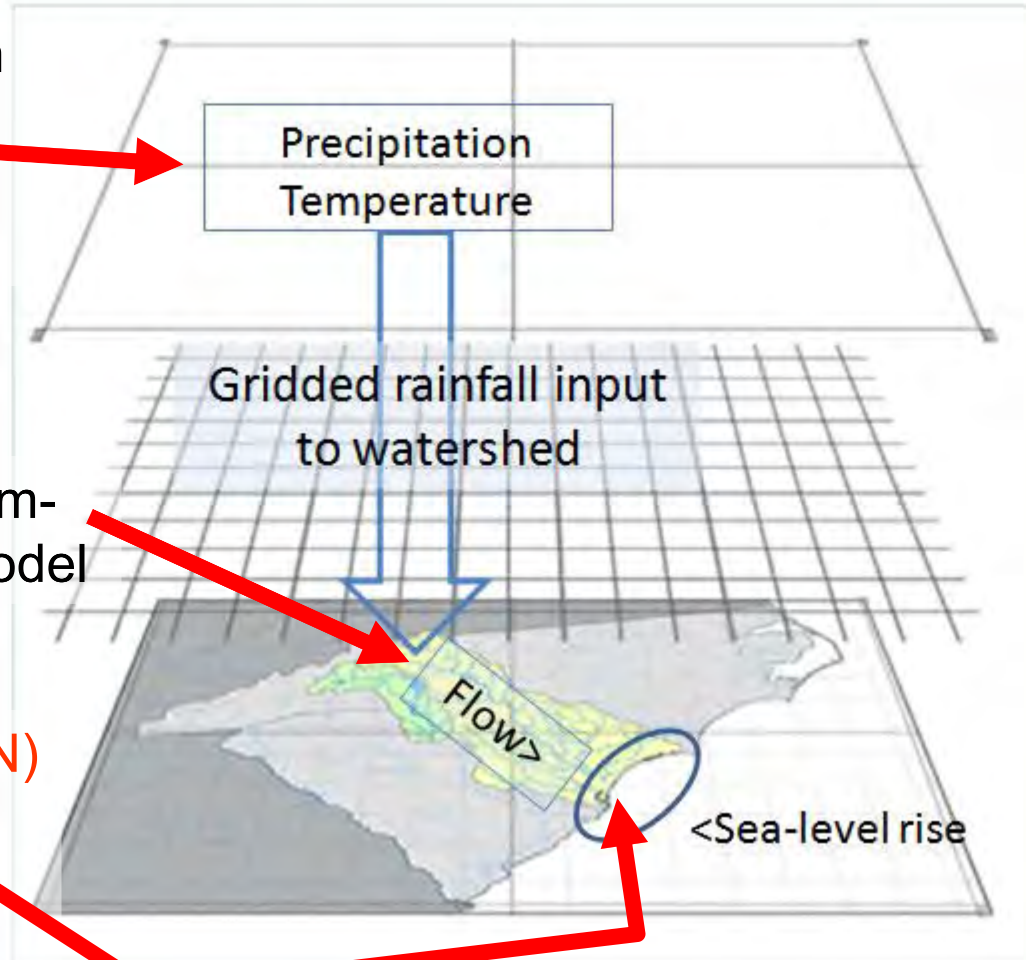


PRISM Calibration

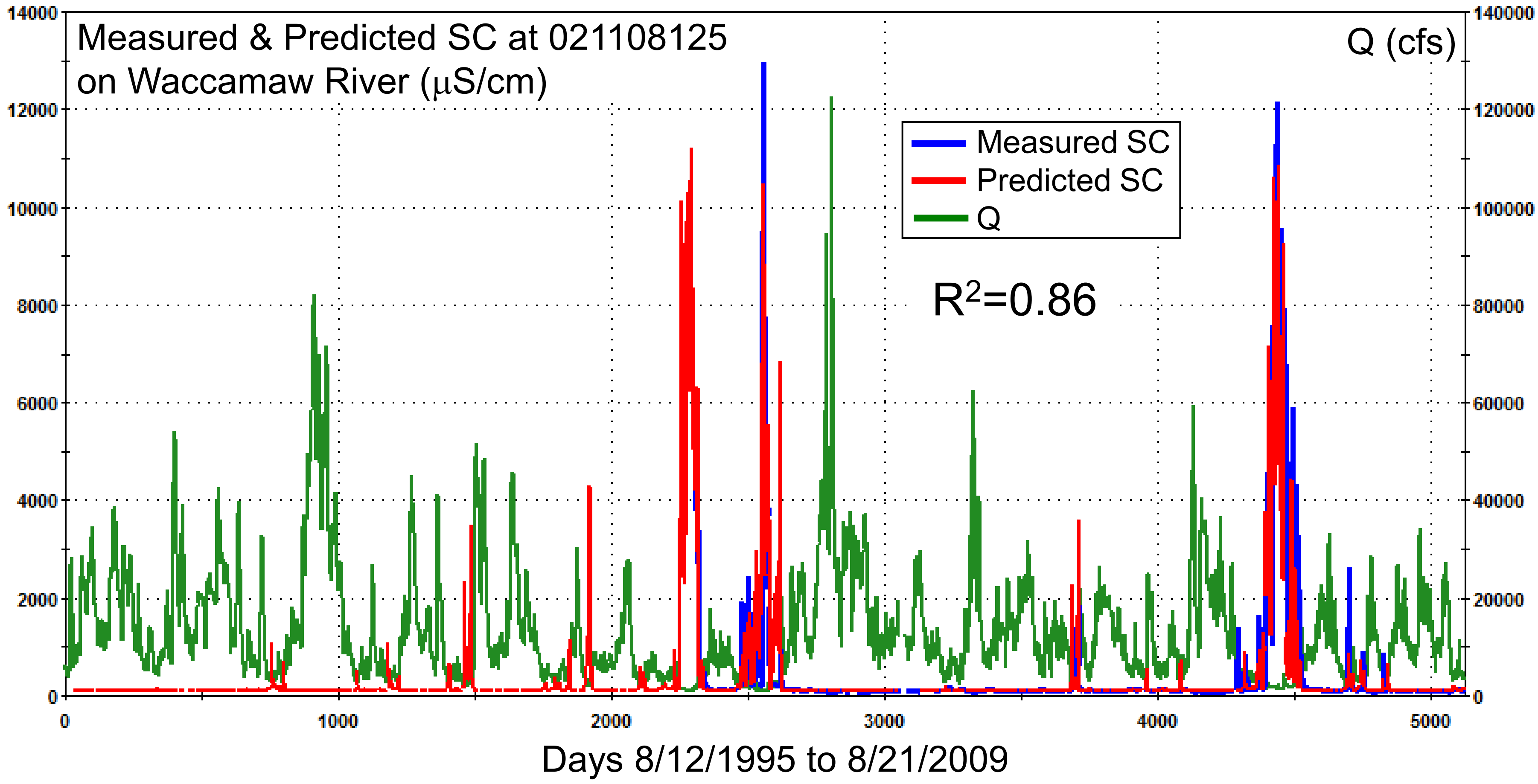
ECHO-G global circulation model (GCM) with A2 future carbon emissions scenario

Hydrologic Simulation Program-Fortran (HSPF) watershed model

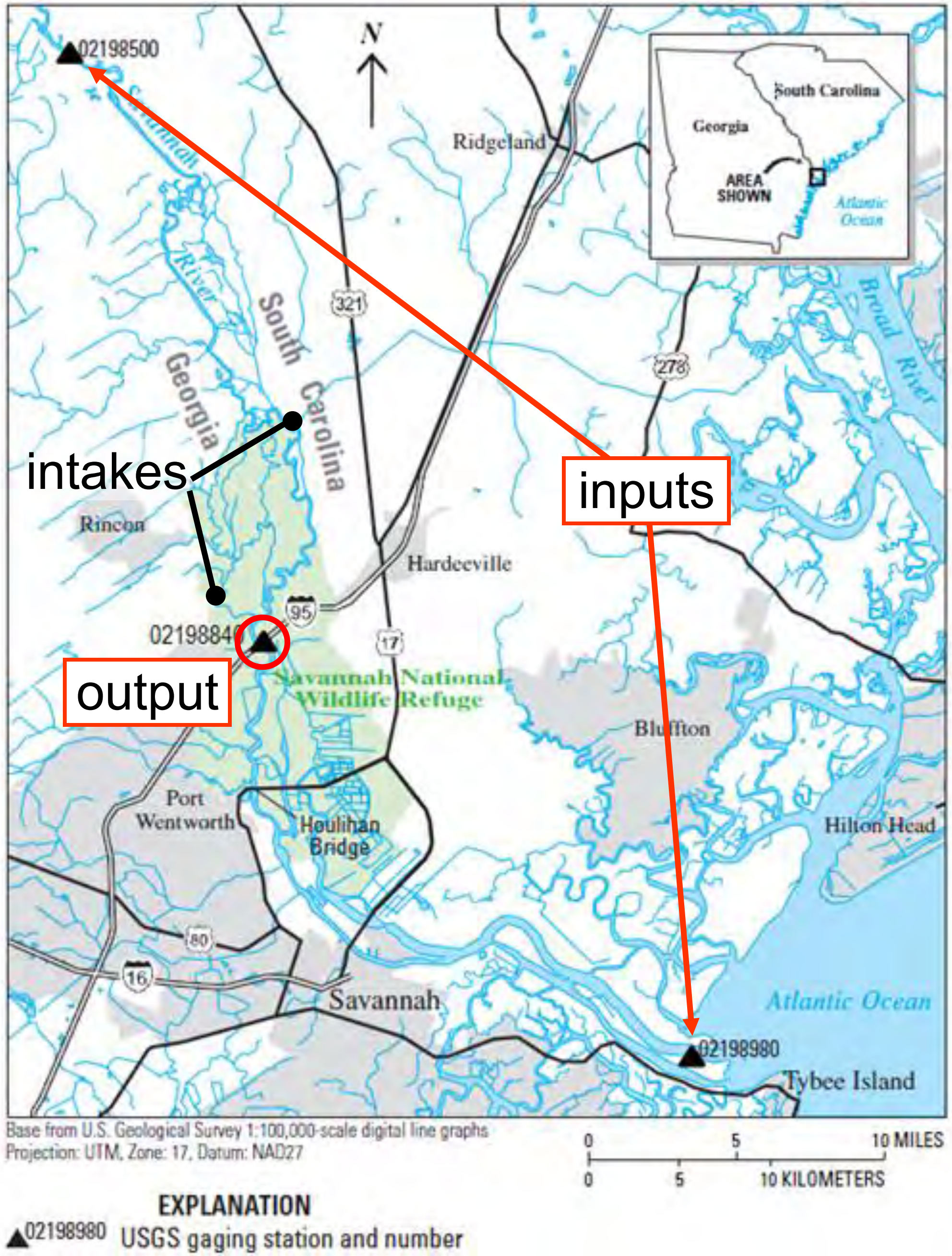
Artificial Neural Network (ANN) estuary models embedded in decision support systems (DSS)



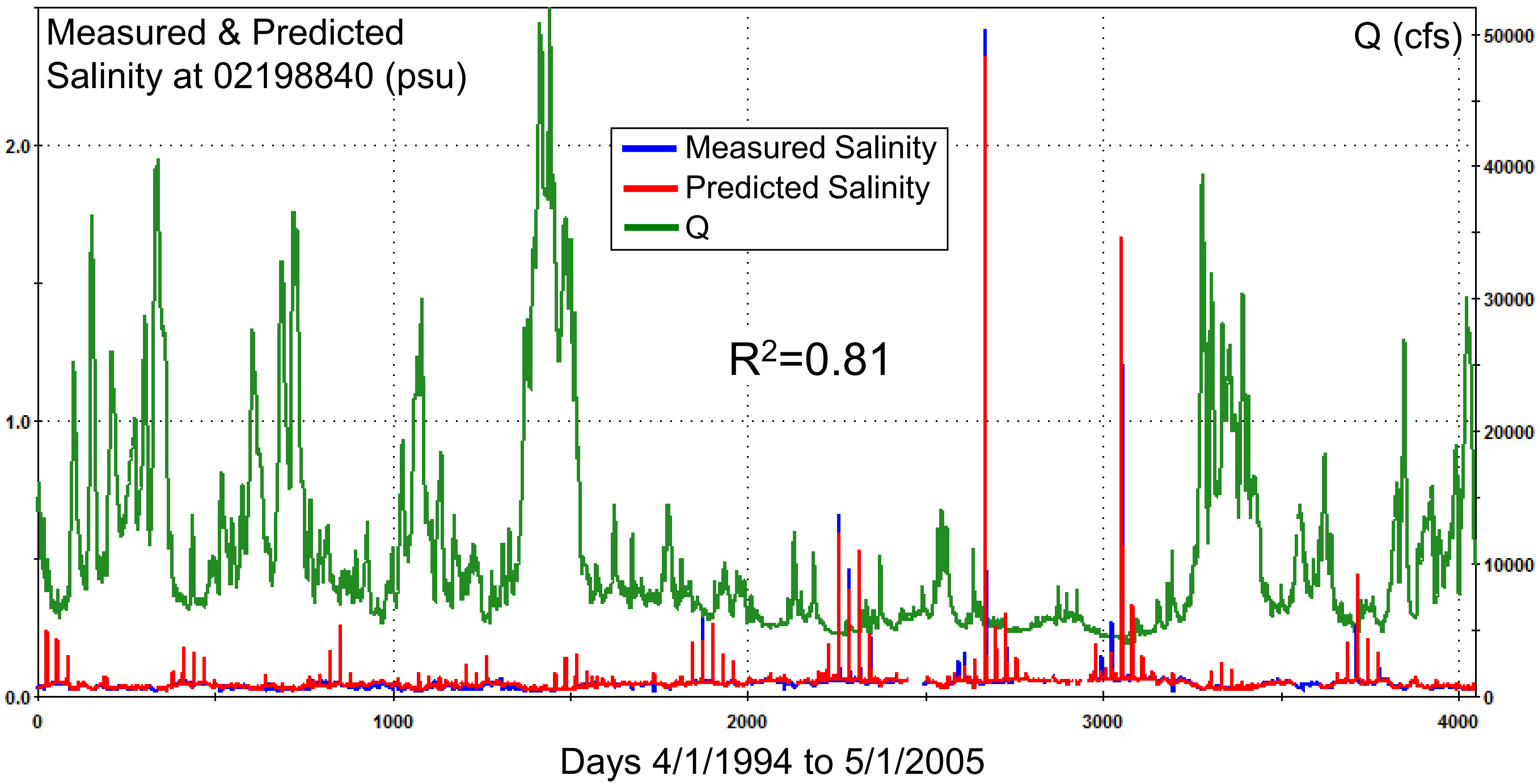
PRISM Calibration (near intake)



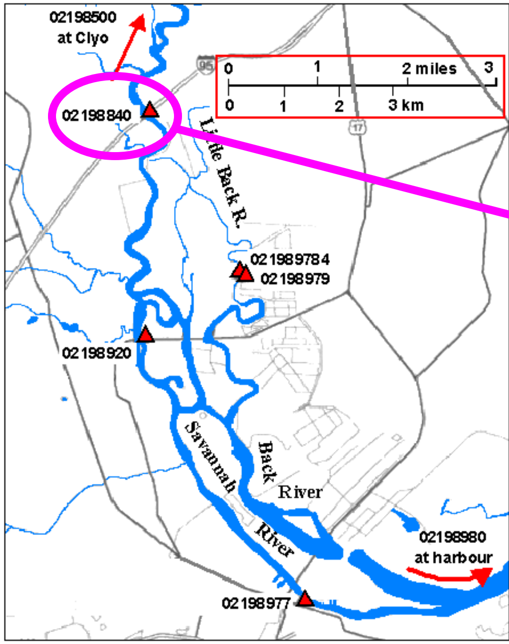
M2M inputs

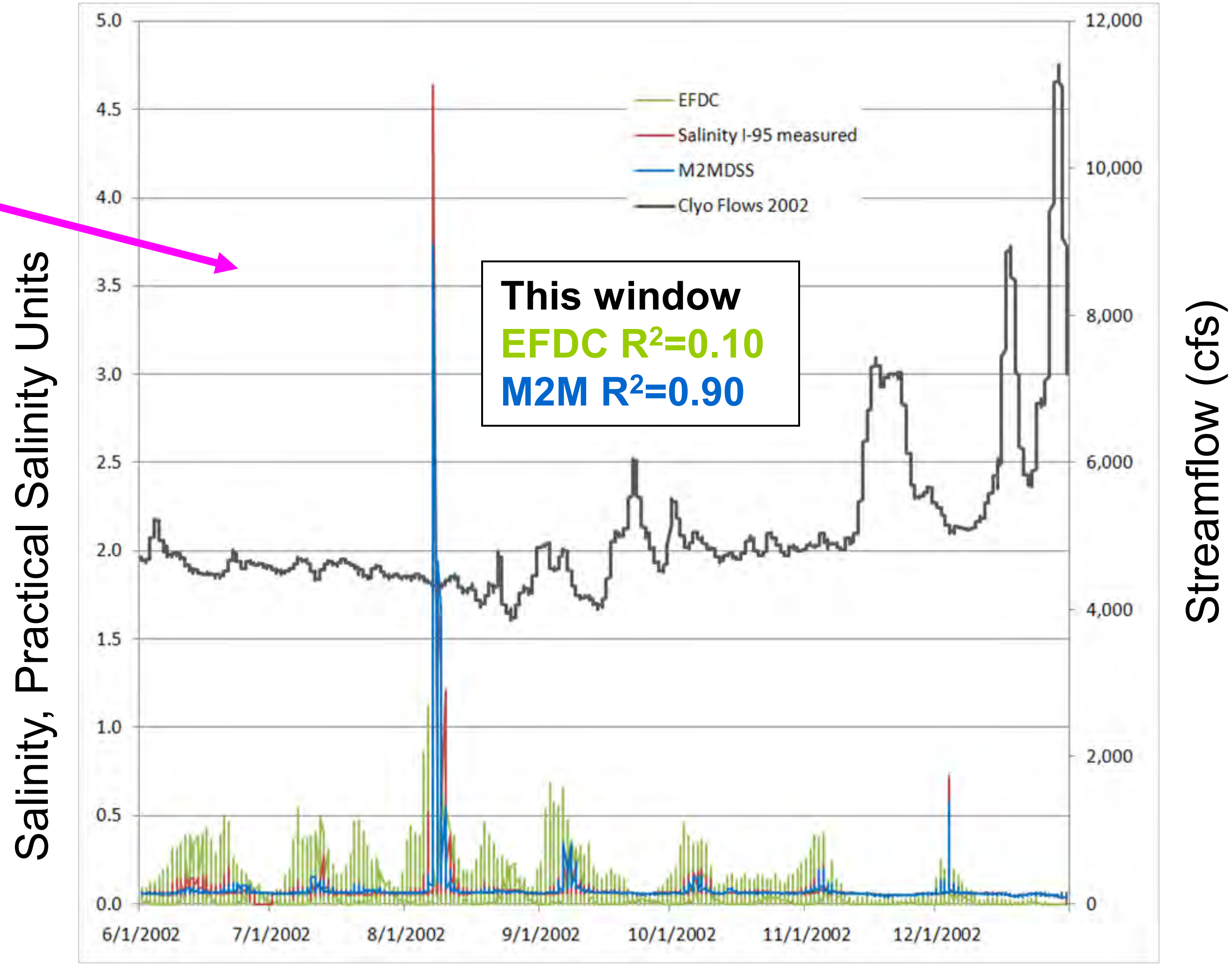

02198500
N
Ridgeland
South Carolina
Georgia
AREA SHOWN
Atlantic Ocean
Savannah River
South Carolina
Georgia
321
278
Broad River
intakes
inputs
Rincon
Hardeeville
95
02198840
17
output
Savannah National Wildlife Refuge
Bluffton
Port Wentworth
Houlihan Bridge
Hilton Head
80
16
Savannah
Atlantic Ocean
02198980
Tybee Island
Base from U.S. Geological Survey 1:100,000-scale digital line graphs
Projection: UTM, Zone: 17, Datum: NAD27
0 5 10 MILES
0 5 10 KILOMETERS
EXPLANATION
02198980 USGS gaging station and number

M2M Calibration



Lower Savannah - EFDC vs. M2M

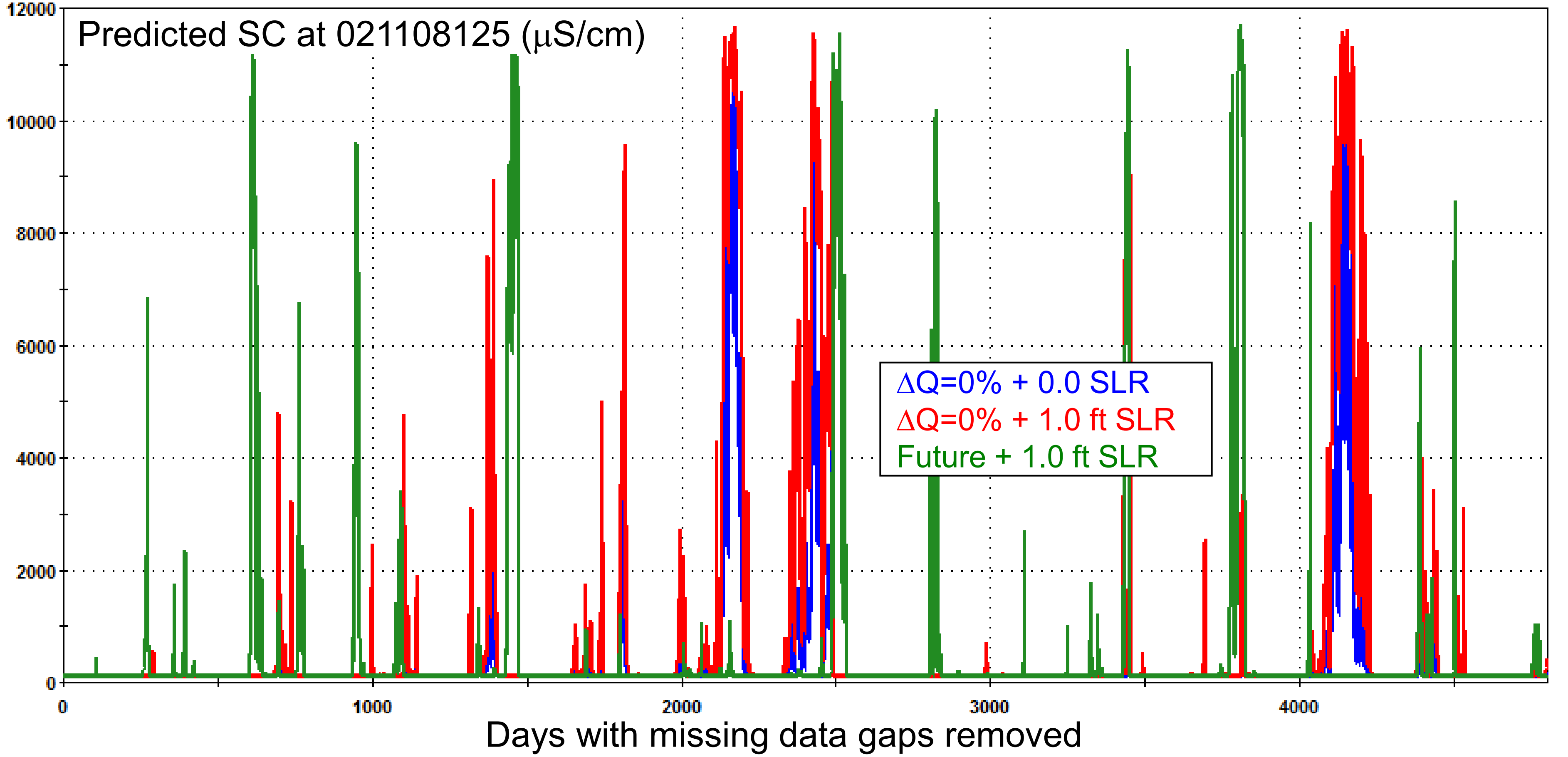




Conrads, P., and Greenfield, J., (2008), “Effects of Reduced Controlled Releases from Lake Thurmond on Salinity Intrusion in the Lower Savannah River Estuary”, 2008 South Carolina Water Resources Conferences.

Pee Dee Basin Results

Pee Dee - 3 prediction scenarios



- ΔQ=0% = historical flow
  - 1.0 ft SLR increases event magnitude and duration
- Future = 1995-2005 study period +60 = 2055-2069
  - ECHO-G with IPCC “business as usual “ A2 emissions scenario
    - Intergovernmental Panel on Climate Change
  - Future is wetter, more events of shorter duration

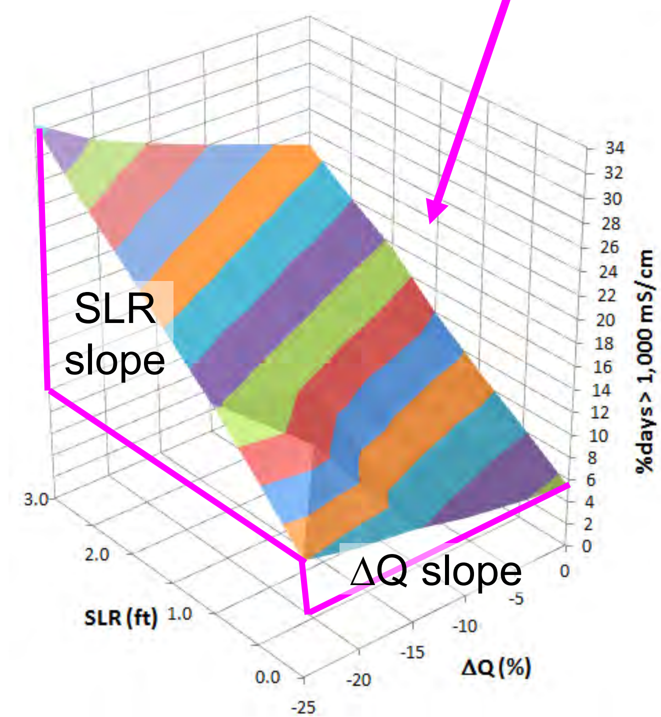
Modulate historical Q and SL ⇒ %days > x µS/cm

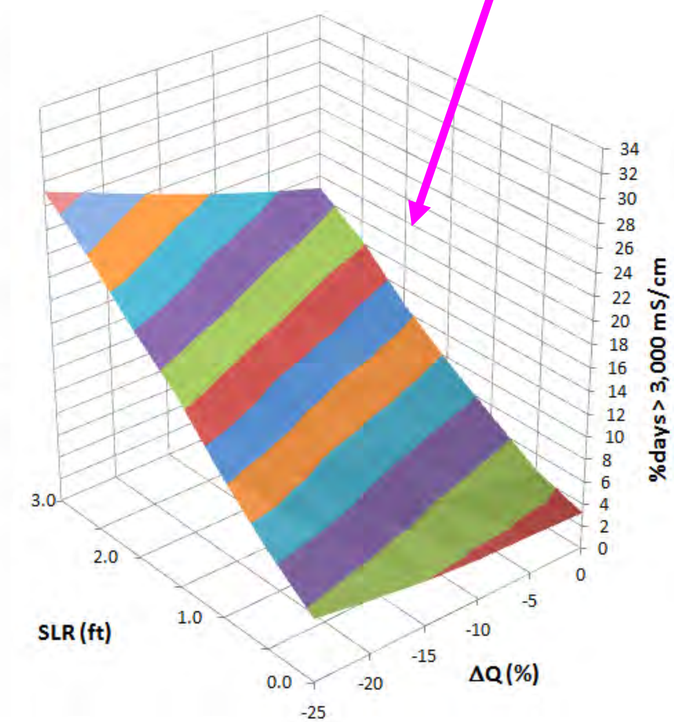
Increase SLR →

Decrease Q ↓

ΔQ/SLR (ft)	%days > 1,000 µS/cm							%days > 2,000 µS/cm							%days > 3,000 µS/cm						
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0
0%	5	8	11	14	18	20	23	4	6	9	11	15	18	20	3	5	7	10	13	16	19
-5%	6	9	12	16	19	22	25	4	7	9	12	16	19	22	3	5	8	11	14	18	20
-10%	7	10	13	17	20	23	26	5	8	11	14	18	20	23	4	6	9	12	16	19	22
-15%	8	11	15	19	22	25	28	5	8	12	16	19	22	25	4	7	10	13	17	20	24
-20%	9	15	17	20	23	27	30	6	9	13	17	20	24	27	5	8	11	15	19	22	25
-25%	10	14	18	22	25	29	33	7	11	15	19	22	26	29	6	9	12	17	20	24	27

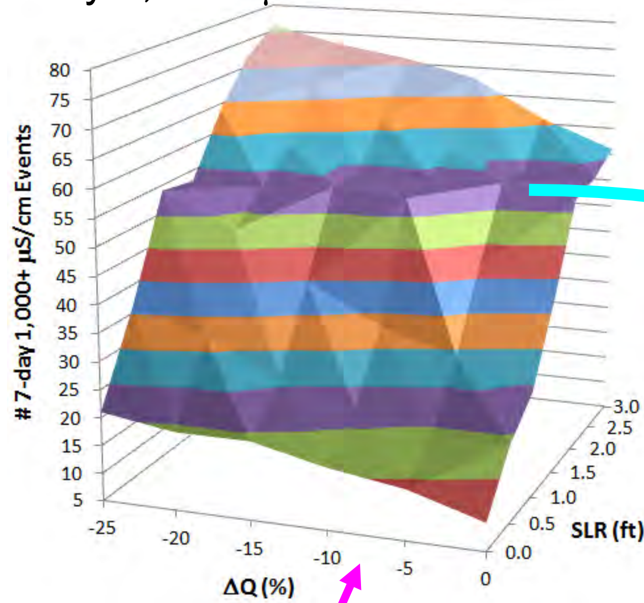
- 42 simulations
- SLR has bigger impact than Q decrease



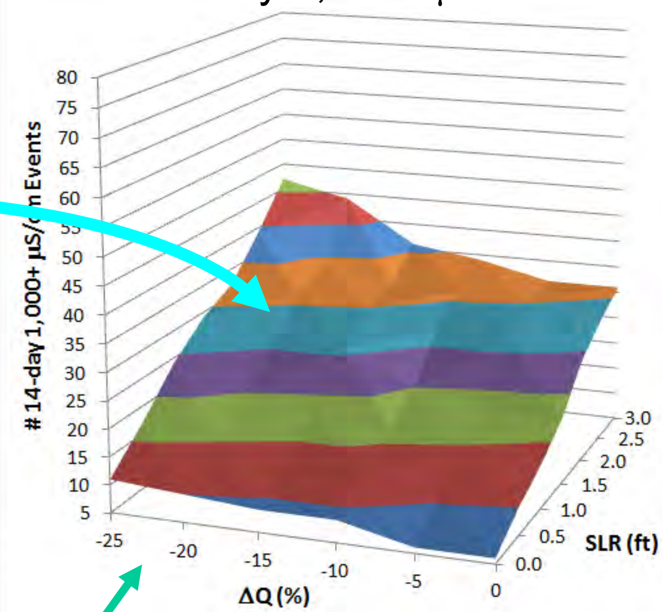


Consecutive day events > x µS/cm

7-day 1,000+ µS/cm events



14-day 1,000+ µS/cm events



#1,000+ µS/cm events

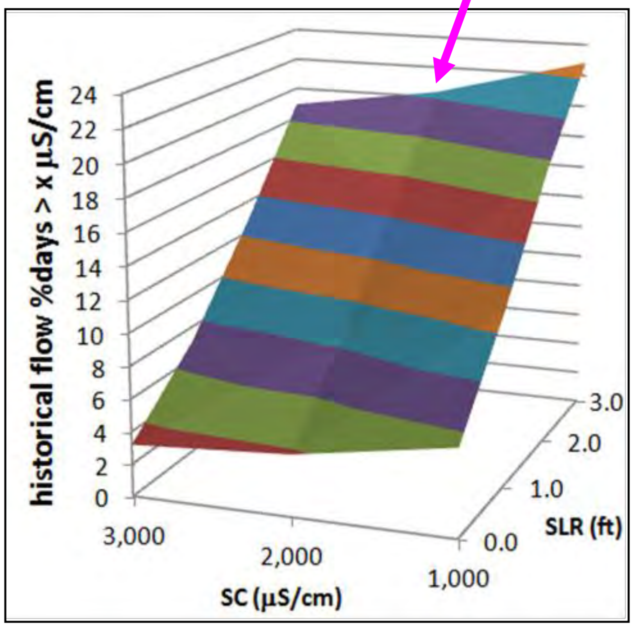
	# 7-day 1,000+ µS/cm Events							# 14-day 1,000+ µS/cm Events							# 21-day 1,000+ µS/cm Events						
ΔQ/SLR (ft)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0
0%	10	19	24	37	52	53	56	6	10	13	17	24	28	31	4	4	5	8	11	14	18
-5%	14	19	29	42	54	53	61	6	11	15	18	27	30	31	4	4	6	10	12	16	18
-10%	16	22	33	53	54	57	68	9	13	16	20	27	31	34	4	4	8	11	13	18	18
-15%	19	26	40	54	54	62	71	9	13	18	26	30	31	36	4	5	10	11	16	18	21
-20%	19	32	48	53	58	68	73	10	15	20	26	31	34	44	4	6	10	17	18	18	21
-25%	21	36	54	53	64	72	76	11	17	24	29	32	39	47	4	8	11	18	18	21	26

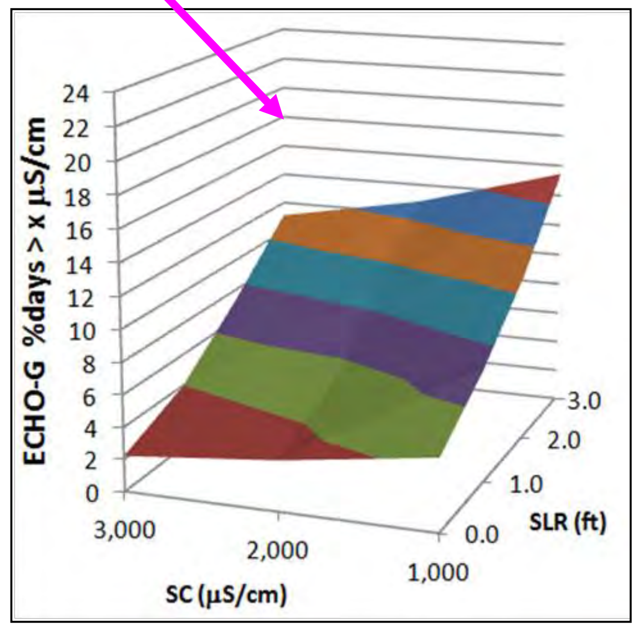
#3,000+ µS/cm events

	# 7-day 3,000+ µS/cm Events							# 14-day 3,000+ µS/cm Events							# 21-day 3,000+ µS/cm Events						
ΔQ/SLR (ft)	0.0	0.5	1.0	1.5	2.0	2.5	3.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0	0.0	0.5	1.0	1.5	2.0	2.5	3.0
0%	7	12	17	25	40	48	51	3	7	11	15	22	24	29	4	4	5	6	9	14	15
-5%	8	15	19	34	41	48	55	3	8	12	17	23	29	31	4	4	6	7	12	15	15
-10%	11	17	21	40	44	51	61	5	8	14	18	24	29	31	4	4	7	8	13	15	18
-15%	11	18	26	40	48	56	66	6	11	16	23	29	30	34	4	5	7	10	15	15	20
-20%	12	19	37	41	50	60	66	8	11	18	24	29	31	41	4	6	7	16	15	18	21
-25%	14	25	39	47	57	64	69	9	13	21	26	30	35	44	4	6	8	17	16	20	23

Compare historical and future %days > x µS/cm

SLR (ft)	%days > 1,000, 2,000, and 3,000 µS/cm								
	historical SC			historical Q			ECHO-G/HSPF Q		
	1,000	2,000	3,000	1,000	2,000	3,000	1,000	2,000	3,000
0.0	7	4	4	5	4	3	4	3	2
1.0				11	9	7	7	5	4
2.0				18	15	13	11	9	7
3.0				23	20	19	15	13	11

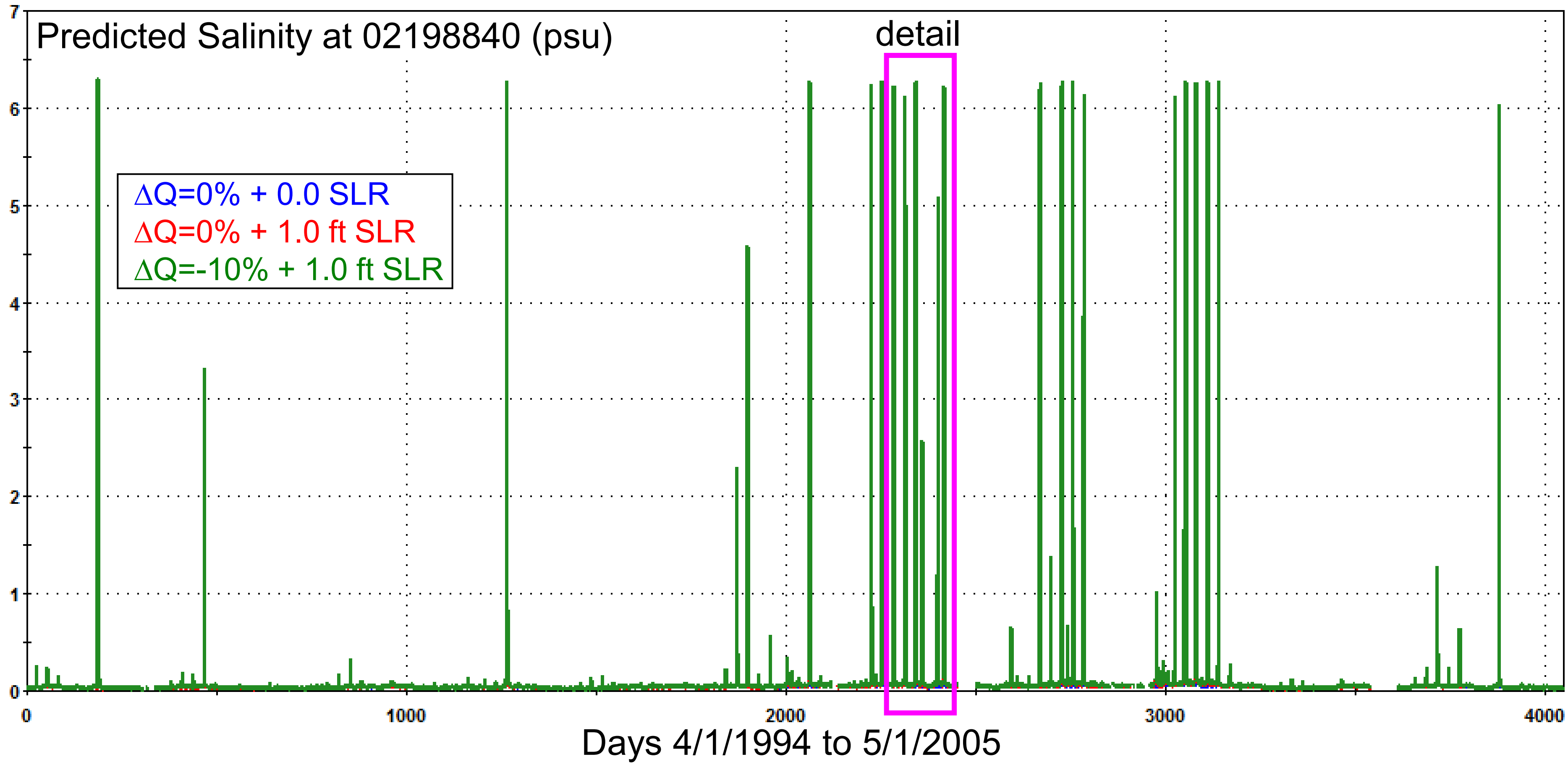




- Predicted wetter future has fewer %days > x

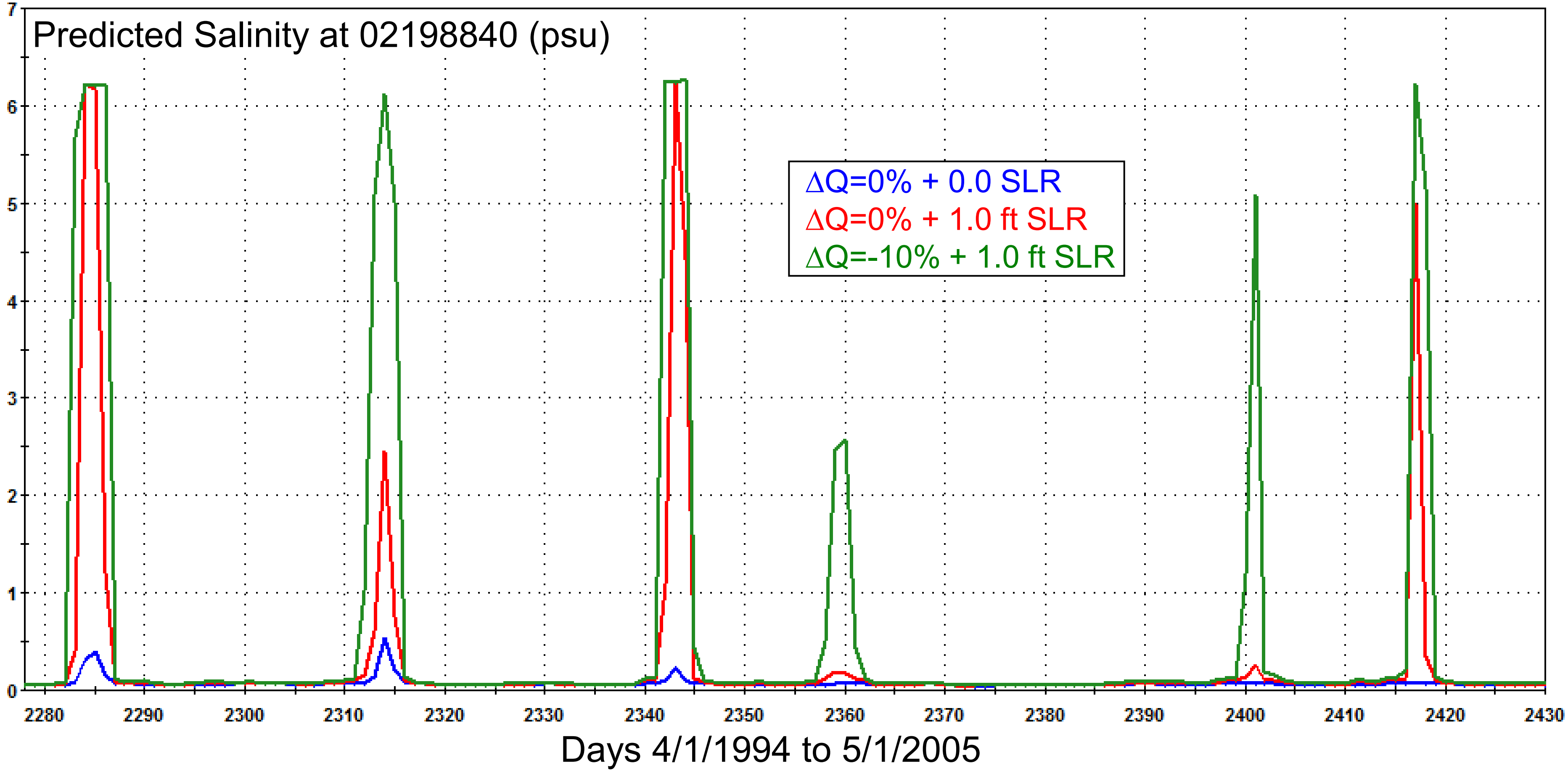
Lower Savannah Results

Savannah - 3 prediction scenarios



- No future scenario for Savannah
- 3rd scenario obscures other 2 – see detail

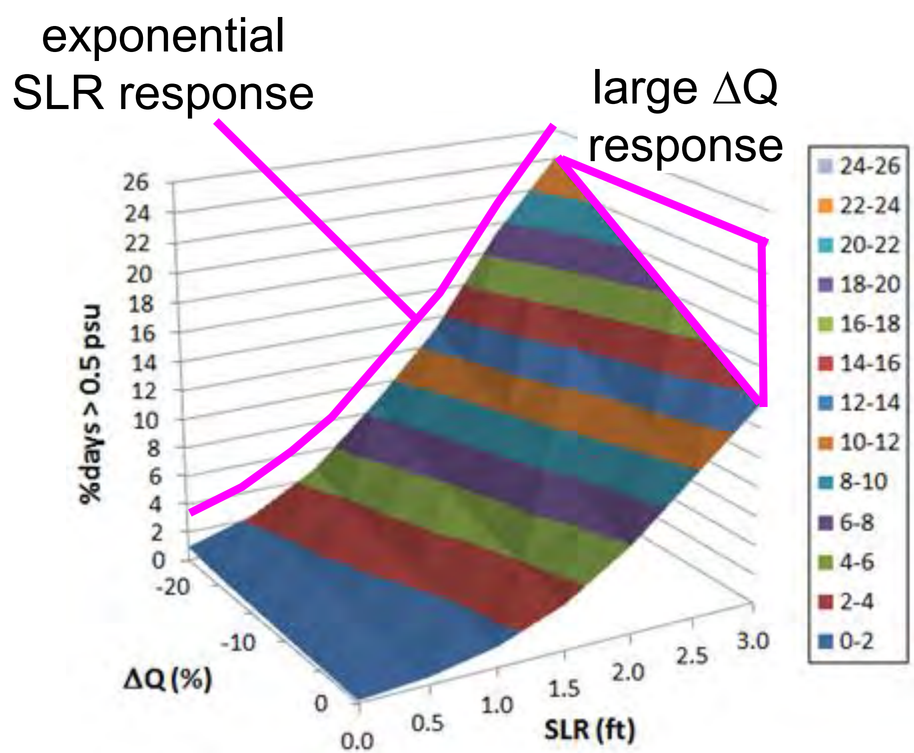
Detail – 3 Savannah scenarios



- 3rd (worst) scenario really is worst!
- Some spikes – ΔQ+SLR effect >> SLR alone
  - unlike Pee Dee

%days > x µS/cm

ΔQ / SLR (ft)	%days > 0.5 psu						
	0.0	0.5	1.0	1.5	2.0	2.5	3.0
0%	0.2	0.5	1.4	3.1	5.9	9.7	13.6
-5%	0.3	0.7	1.8	3.9	7.0	11.2	15.4
-10%	0.4	0.9	2.3	4.6	8.6	12.5	17.7
-15%	0.5	1.4	3.0	5.8	10.0	14.5	20.0
-20%	0.6	1.7	3.8	7.1	11.4	16.8	22.0
-25%	1.0	2.2	4.7	8.7	13.3	19.3	24.1



Conclusions

Conclusions

- The Method
  1. Site-specific estuary model needed to credibly assess vulnerability
     - empirical model may be
       - more accurate
       - easier to develop, operate, and update with new data
       - faster turn-around for "What ifs?"
  2. Long-term, site-specific data needed to calibrate model
     - past behaviors likely span much of future range
     - droughts, hurricanes / storms, El Nino
     - If in hand, ready to model. If not, start collecting.
  3. Run scenarios $\Rightarrow$ easy-to-understand tables & graphs
     - modify historical data
     - future forecasts, e.g., GCM+carbon emissions scenarios
- Method applicable to other resources, e.g., groundwater.