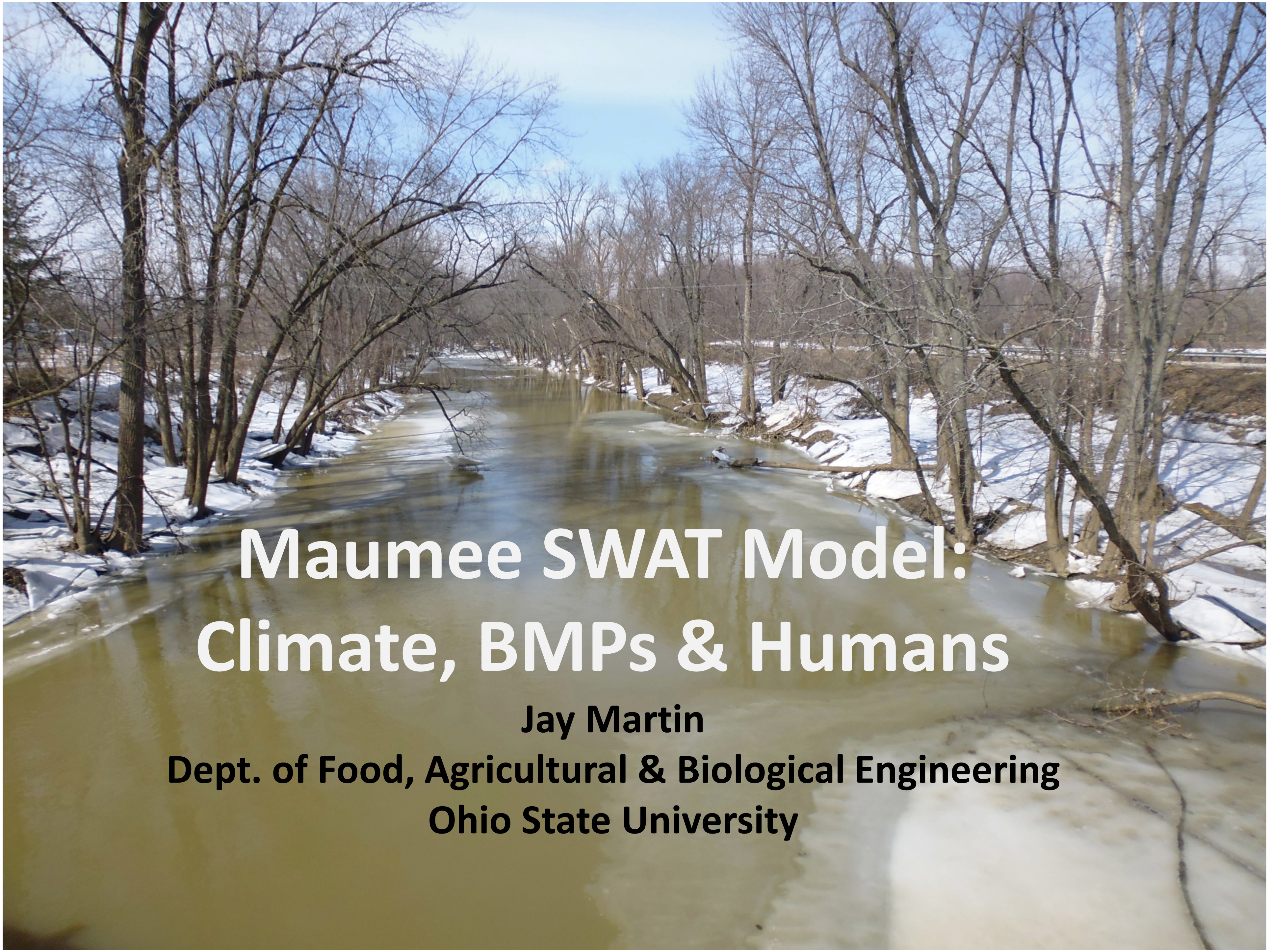
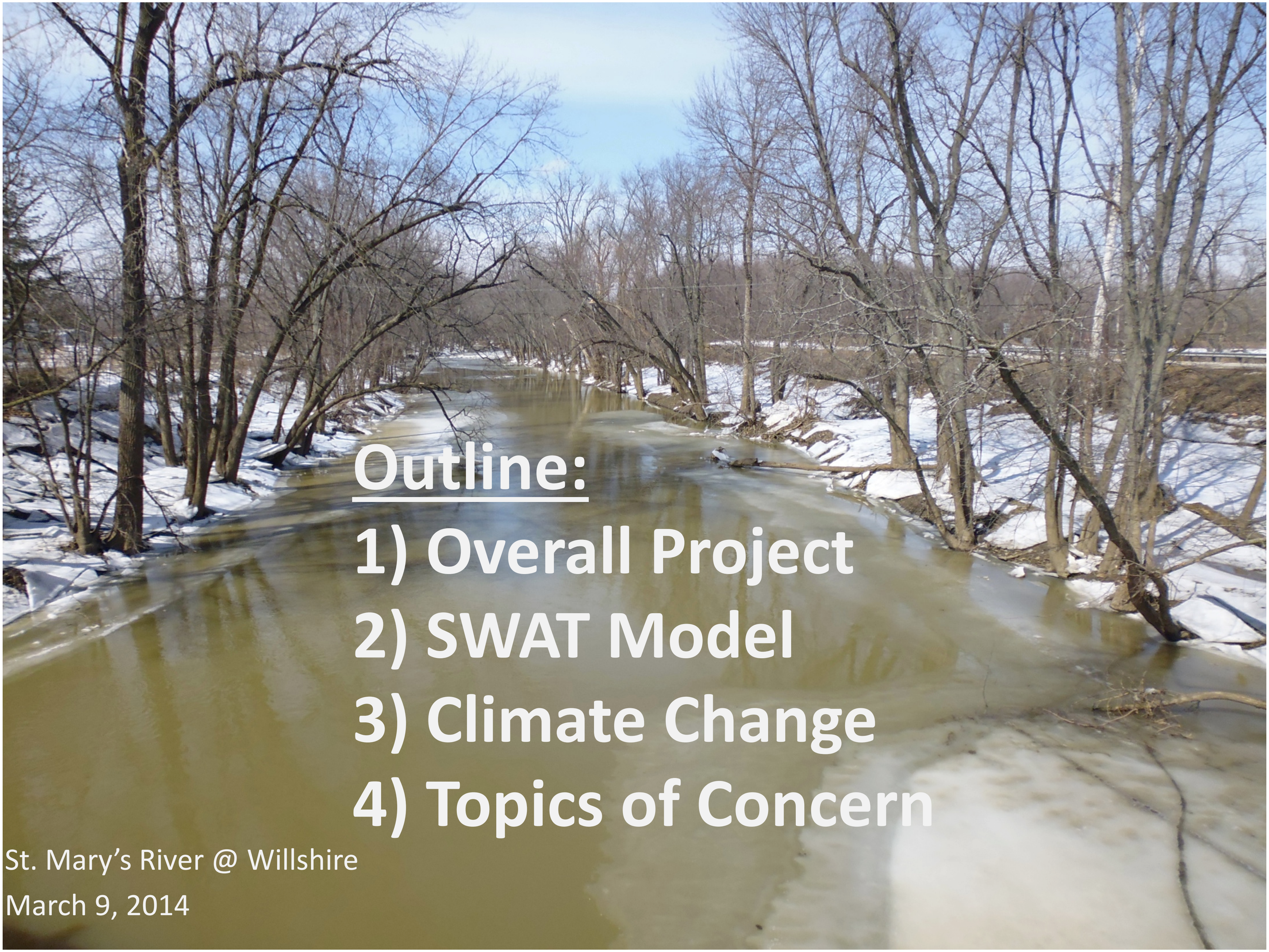
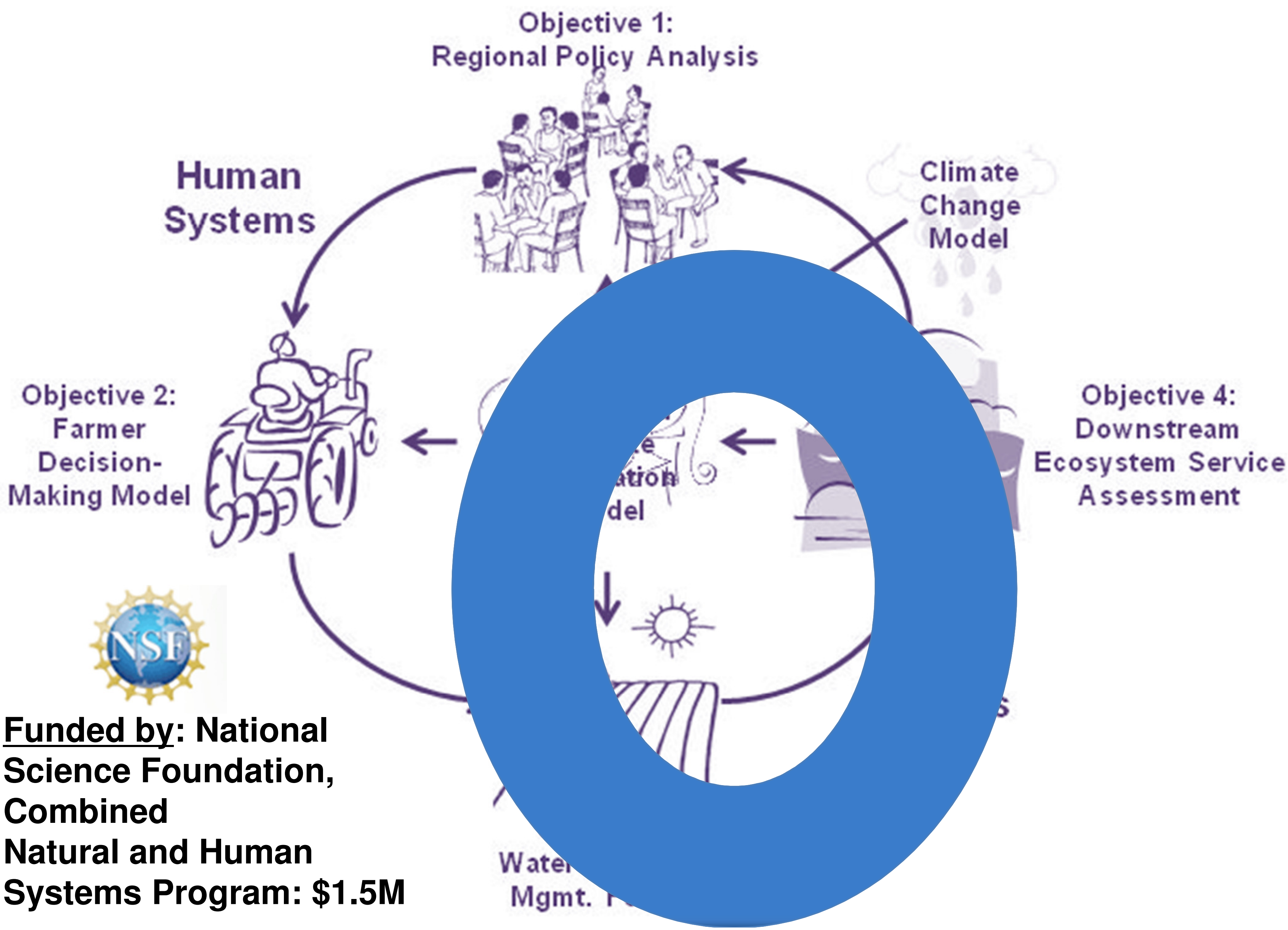


Maumee SWAT Model: Climate, BMPs & Humans

Jay Martin
Dept. of Food, Agricultural & Biological Engineering
Ohio State University


Outline:
1) Overall Project
2) SWAT Model
3) Climate Change
4) Topics of Concern
St. Mary's River @ Willshire
March 9, 2014

Project Background



<u>Funded by</u>: National Science Foundation, Combined Natural and Human Systems Program: $1.5M

Faculty: Jay Martin (PI), Robyn Wilson, Elena Irwin, Stu Ludsin, Erik Nisbet, Eric Toman, Brian Roe, Carlo DeMarchi

Post-Doctoral Researchers: Seyoum Gebremariam, ???

Graduate Students: Marie Gildow, Andreas Culbertson, Alex Heeren, Lizzy Burnett, Wendong Zhang, Na Chen, Greg Howard

Project Website

http://ohioseagrant.osu.edu/maumeebay/

Teaching & Learning Collaborative

NSF

Ohio Division of Wildlife

Michigan Dept. of Natural Resources

National Wildlife Federation

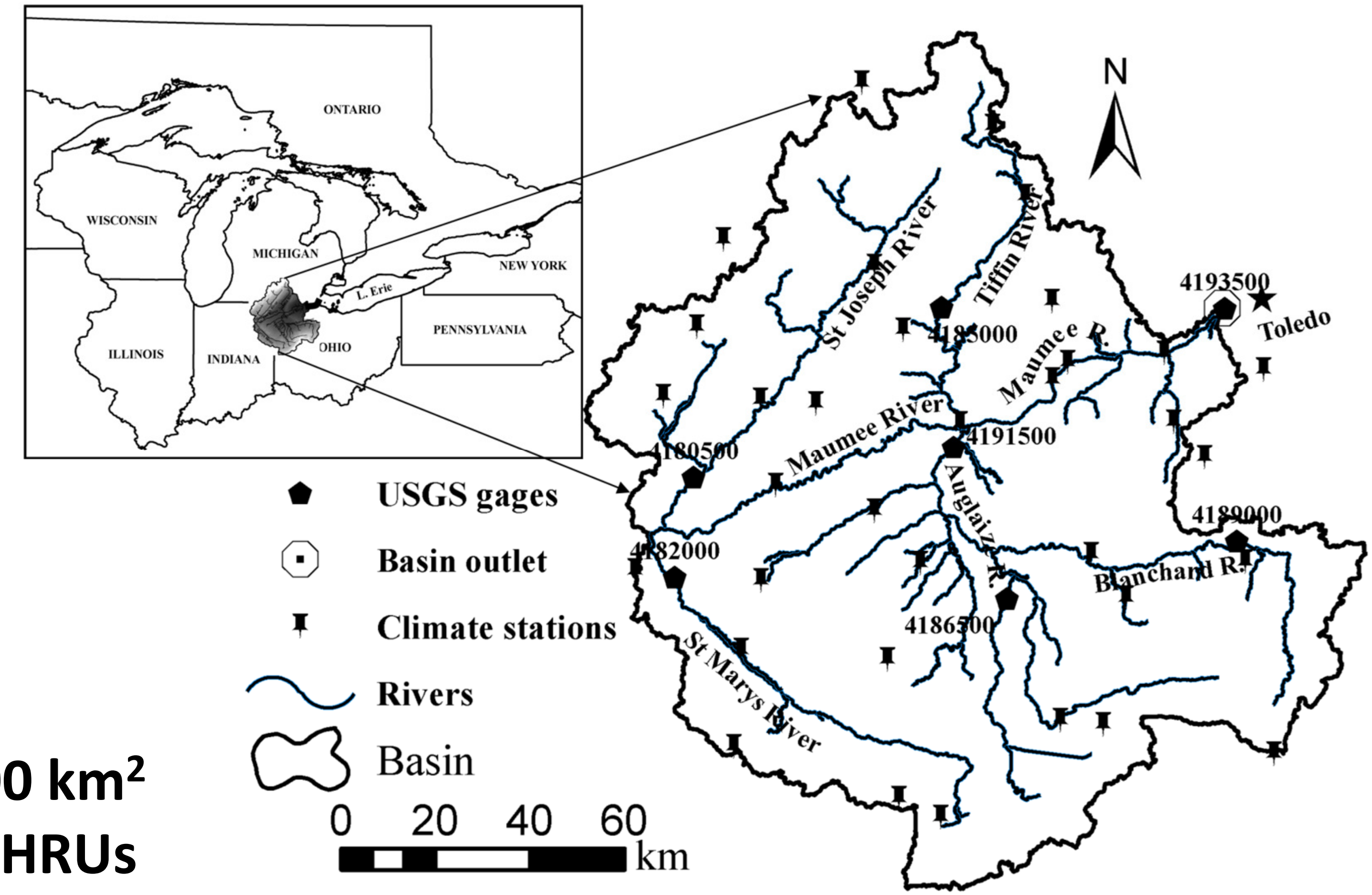
Partners for Clean Streams

Ontario

Sea Grant
Ohio Sea Grant College Program

Pennsylvania Fish and Boat Commission

Maumee SWAT Model



- **17,000 km^2**
- **3000 HRUs**
- **252 subwatersheds**
- **HUC 12**

INPUT DATA

Data	Source
Topography	USGS Digital Elevation Model data (30*30 m)
Hydrography	USGS National Hydrography data
HUC12 WBD	NRCS
Land use	NASS CDL
Soil	USDA SSURGO Soil database
Weather	NOAA National Climatic Data Center
Stream gage	USGS
Water quality	Heidelberg University and USGS

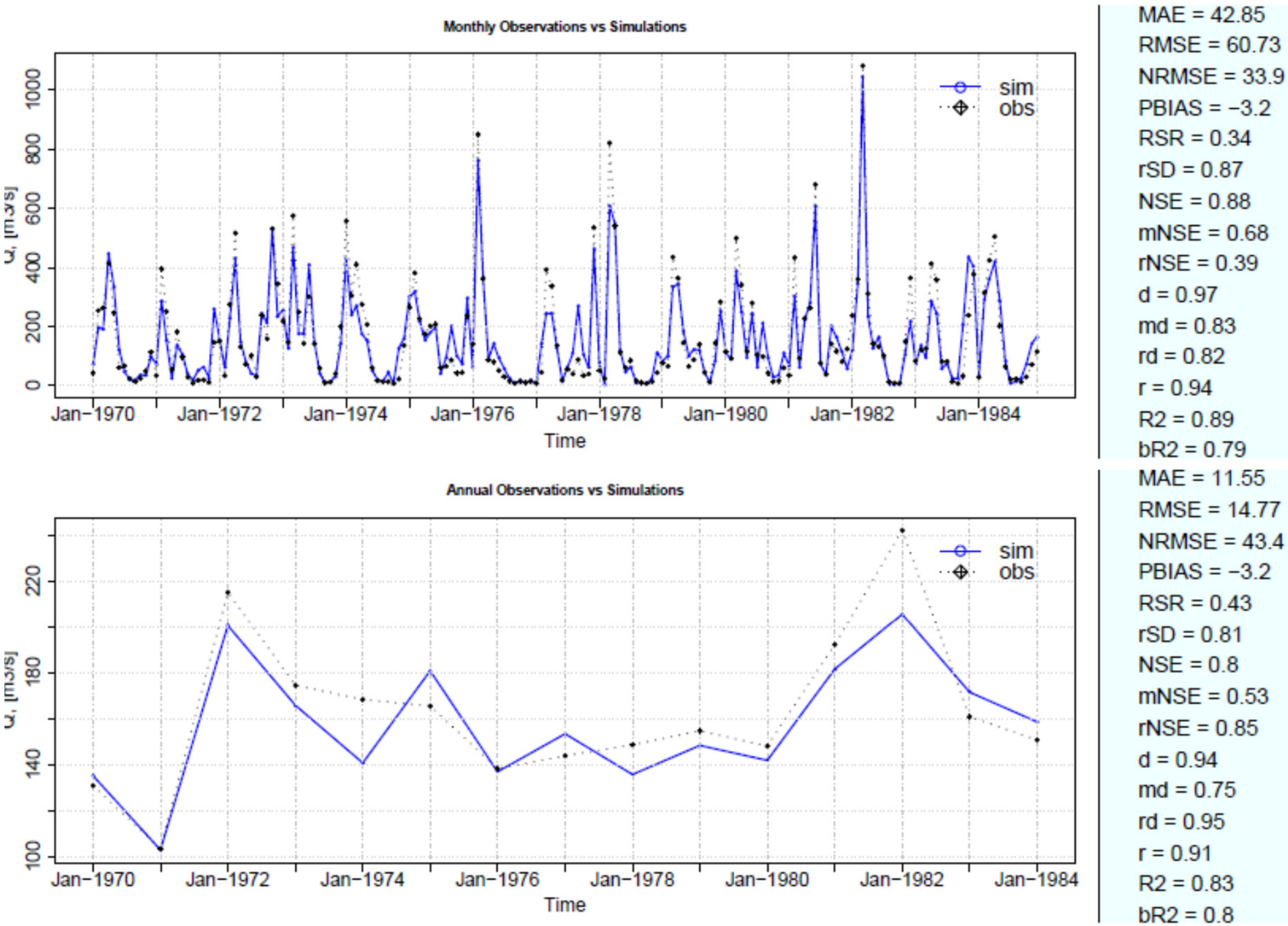
Calibration & Validation for Climate Change Analysis:

Calibration period: 1970-1984

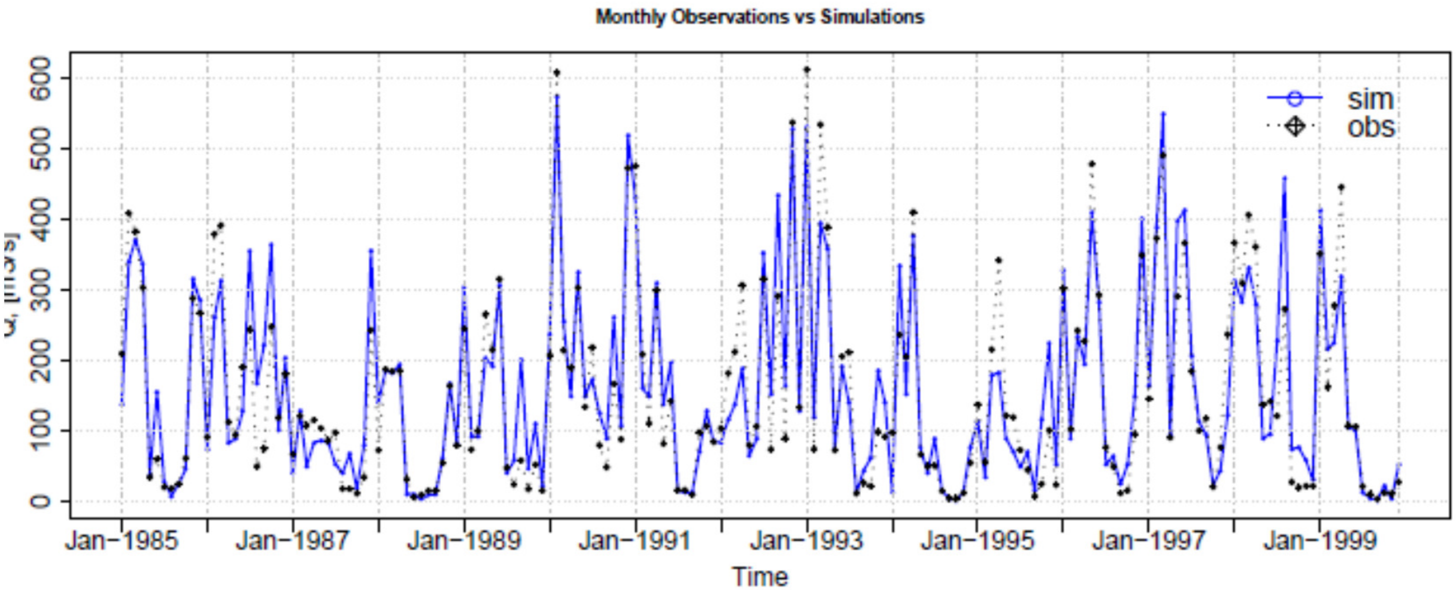
Forward Validation: 1985-1999

Backward Validation: 1955-1969

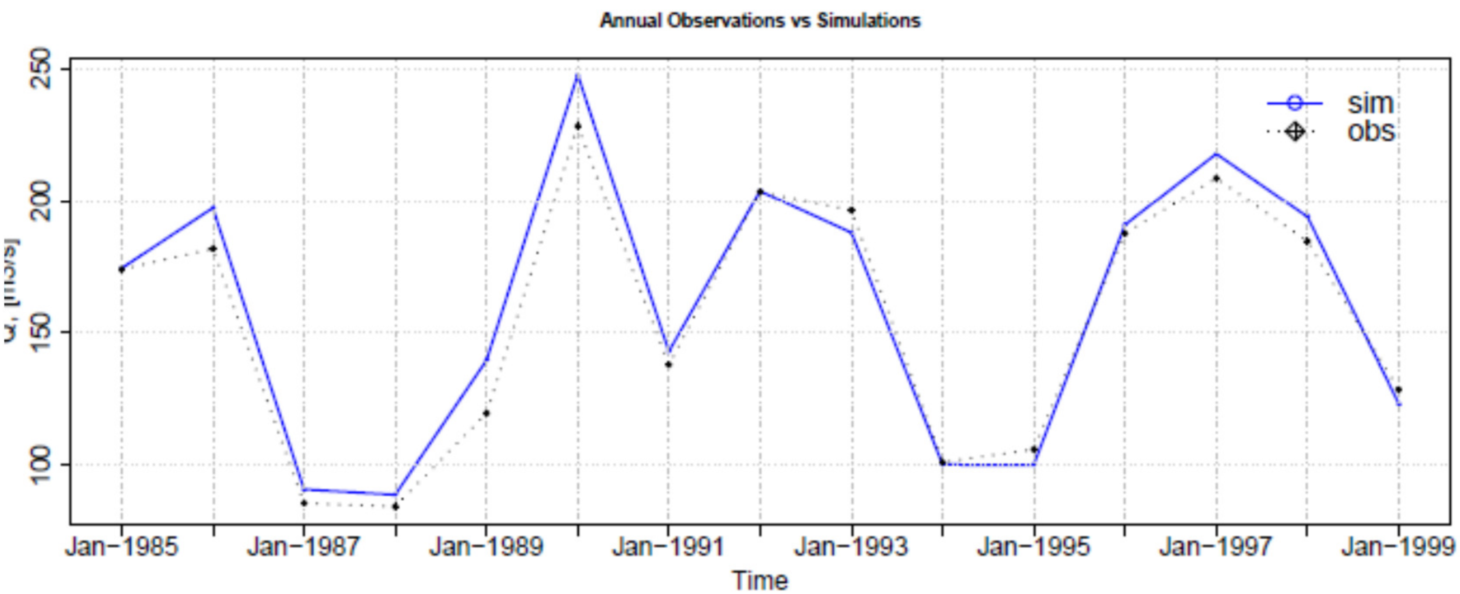
Calibration (@ Waterville)



Forward Validation (@ Waterville)



MAE = 39.88
RMSE = 54.96
NRMSE = 39.5
PBIAS = 3.1
RSR = 0.4
rSD = 0.97
NSE = 0.84
mNSE = 0.65
rNSE = 0.33
d = 0.96
md = 0.82
rd = 0.82
r = 0.92
R2 = 0.85
bR2 = 0.82



MAE = 7.49
RMSE = 9.66
NRMSE = 20
PBIAS = 3.1
RSR = 0.2
rSD = 1.06
NSE = 0.96
mNSE = 0.83
rNSE = 0.95
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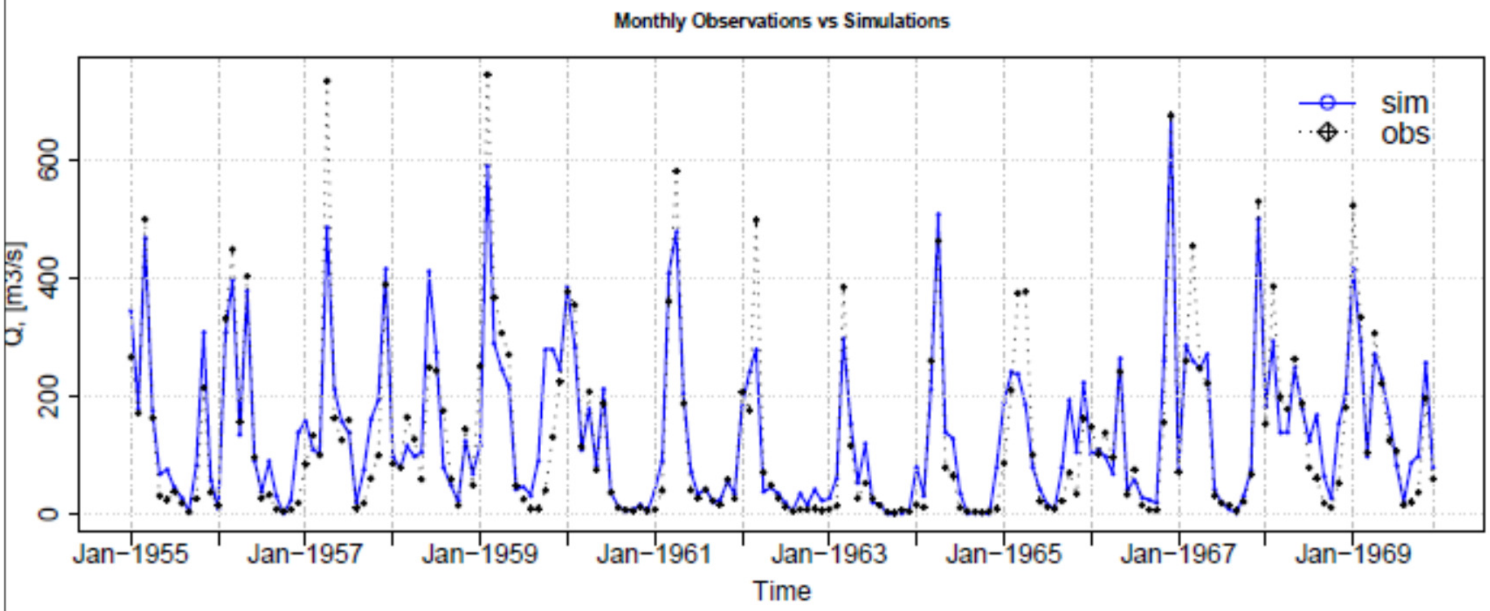
md = 0.91
rd = 0.99
r = 0.99
R2 = 0.97
bR2 = 0.94

Backward Validation(@ Waterville)



MAE = 39.74
RMSE = 60.93
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RSR = 0.4
rSD = 0.86
NSE = 0.84
mNSE = 0.66
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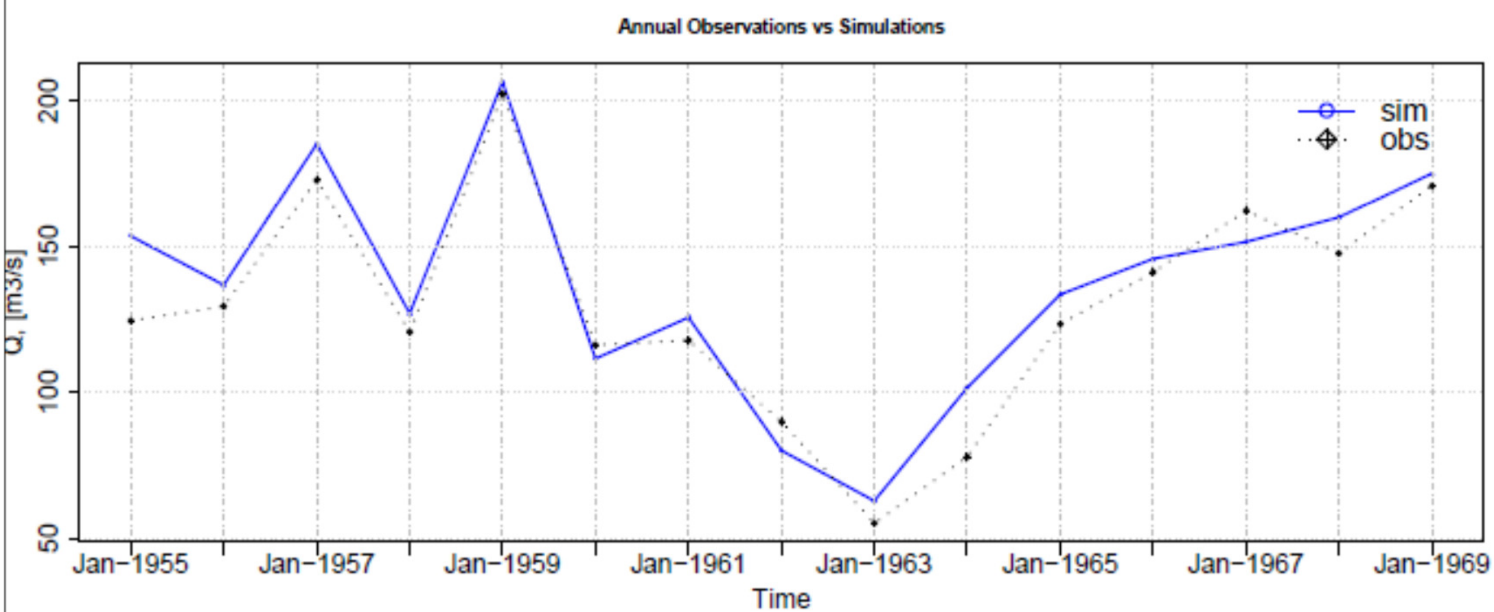
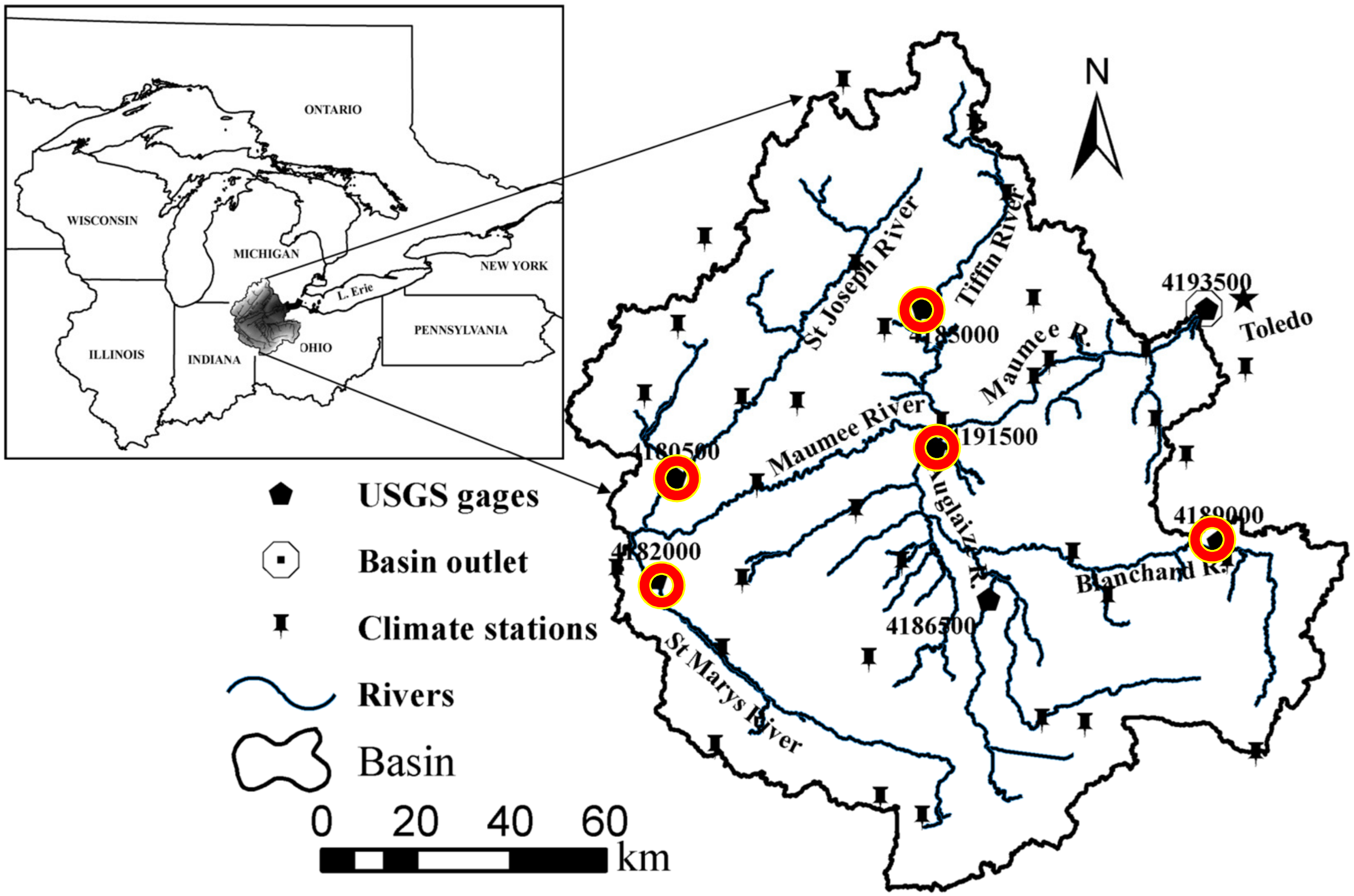
r = 0.92
R2 = 0.85
bR2 = 0.76



MAE = 10.31
RMSE = 12.39
NRMSE = 32.3
PBIAS = 5.3
RSR = 0.32
rSD = 1
NSE = 0.89
mNSE = 0.64
rNSE = 0.82
d = 0.97
md = 0.82
rd = 0.96
r = 0.96
R2 = 0.92
bR2 = 0.88

Validation at Upstream Gauges



Model Verification @ Upstream Gages

- Flow (2003-2010)

	Auglaize Defiance		StMarys FortWayne		StJoseph FortWayne		Blanchard Findlay		Tiffin Stryker	
	D	M	D	M	D	M	D	M	D	M
PBIAS	13.60	13.50	-1.10	-1.30	-2.90	-3.10	5.70	5.80	0.10	-0.10
NSE	0.72	0.87	0.78	0.87	0.71	0.82	0.58	0.84	0.58	0.77
R2	0.74	0.89	0.78	0.87	0.74	0.82	0.60	0.84	0.60	0.77

Model Verification @ Upstream Gages

- Flow (2003-2010)

	Auglaize Defiance		StMarys FortWayne		StJoseph FortWayne		Blanchard Findlay		Tiffin Stryker	
	D	M	D	M	D	M	D	M	D	M
PBIAS	13.60	13.50	-1.10	-1.30	-2.90	-3.10	5.70	5.80	0.10	-0.10
NSE	0.72	0.87	0.78	0.87	0.71	0.82	0.58	0.84	0.58	0.77
R2	0.74	0.89	0.78	0.87	0.74	0.82	0.60	0.84	0.60	0.77

Comparison SWAT vs HSPF upstream gauges

Table 4. Monthly validation (2003-2009) NSE and PBIAS (in parenthesis) for six interior USGS gage stations

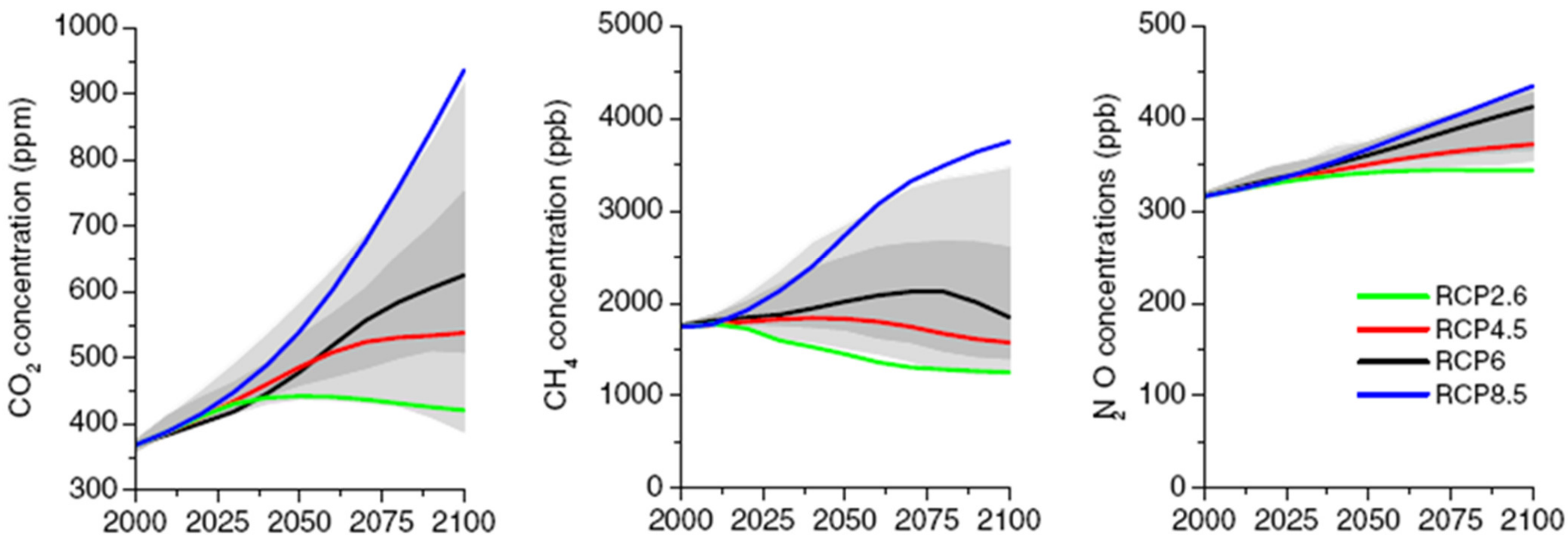
USGS Gage	Tributary	Drainage Area (km^2)	Models		
			DLBRM	HSPF	SWAT
4191500	Auglaize (Defiance, OH)	6004.0	0.77 (-12.9)	0.87 (-3.4)	0.70 (0.6)
4186500	Auglaize (Fort Jennings, OH)	860.0	0.74 (-7.8)	0.86 (-10.4)	0.62 (-5.3)
4189000	Blanchard (Findlay, OH)	896.0	0.7 0(-16.5)	0.65 (-23.0)	0.53 (4.2)
4182000	St Marys (Fort Wayne, IN)	1974.0	0.79 (14.2)	0.90(14.6)	0.69 (-14.4)
4185000	Tiffin (Stryker, OH)	1062.0	0.79 (-0.9)	0.77 (1.7)	0.28 (30.3)
4180500	St Joseph (Fort Wayne, IN)	2745.0	0.84 (-3.4)	0.77 (14.4)	0.75 (2.1)

Projected Climate Summary

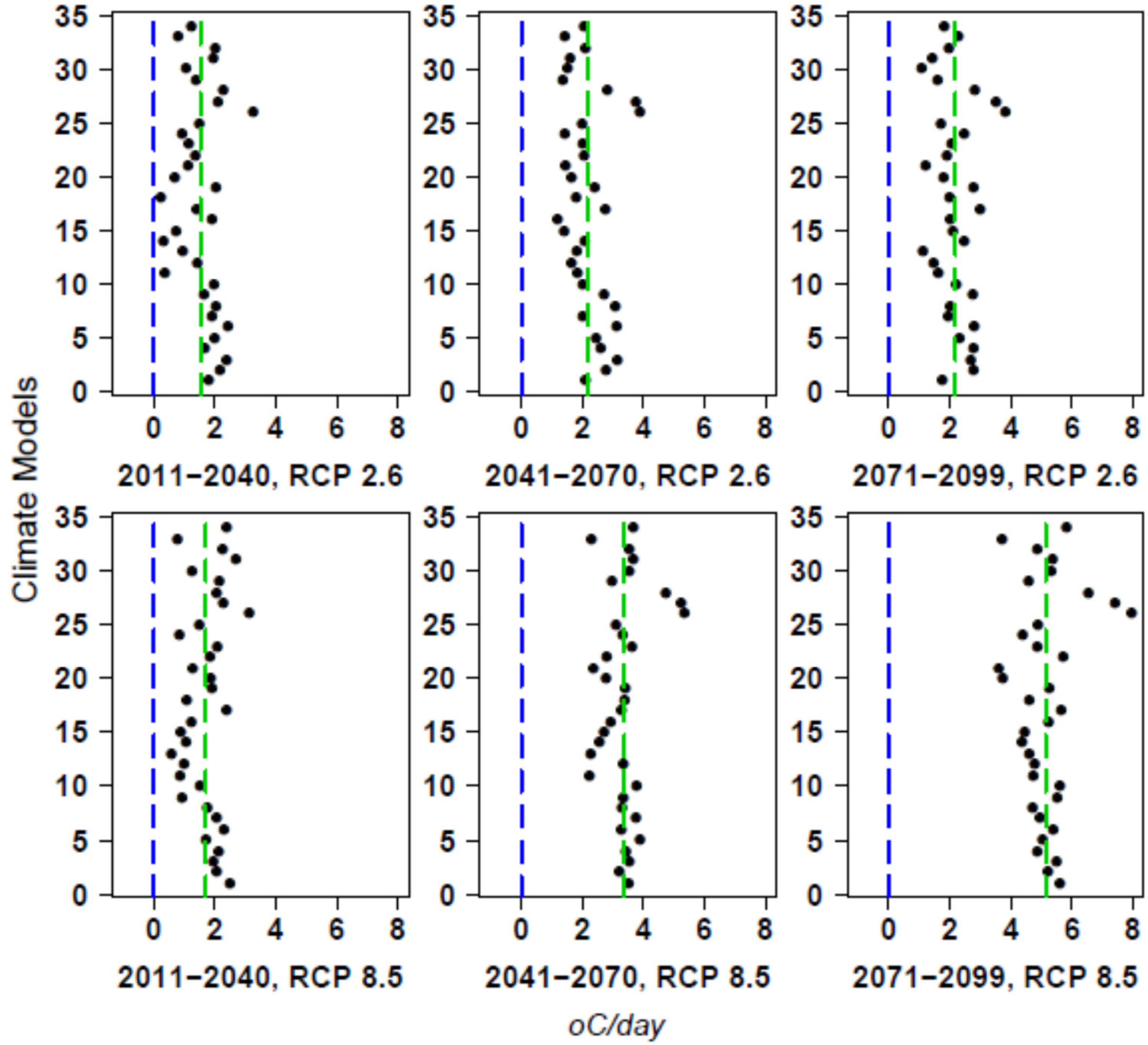
- 36 global climate models
  - Have 2.6 and 8.5 RCP scenarios
  - Downscaled CMIP5 Climate Projections(1950-2099)
  - Spatial resolution of climate data (1/8 degree resolution)
  - 1950-99: Used as historical background/base case
  - In Maumee basin no historical trend precip. & temp.—corrected bias.
  - Future 2011-2099
    - Near future: 2011-2040
    - Mid century: 2041-2070
    - End of century: 2071-2099

CO_2 & Climate Data

- CO_2 data (1951-2100)—SWAT was modified
  - Historical CO_2—global observed data
  - Projected CO_2- IPCC- CMIP5



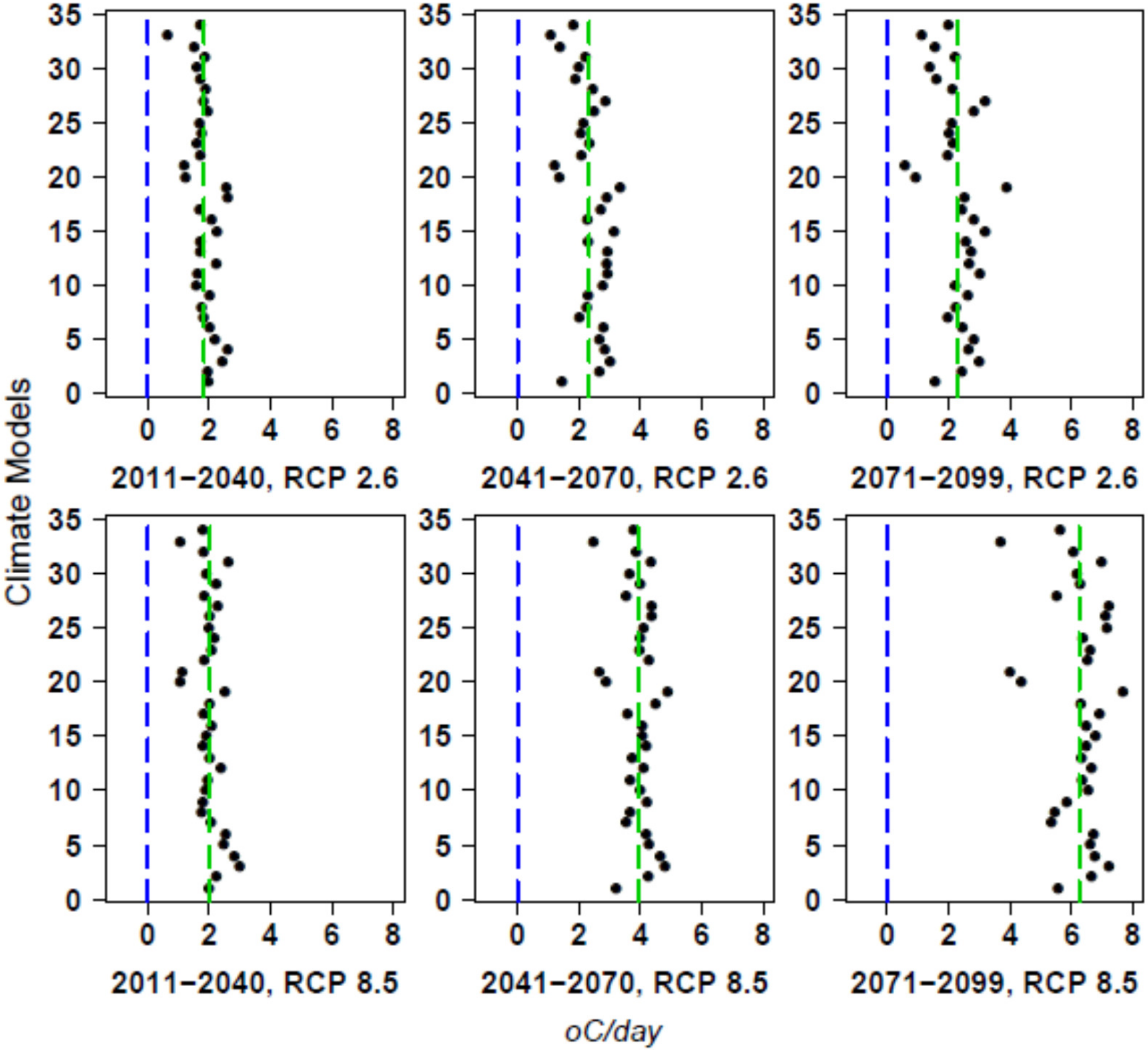
Winter Temp. Predictions



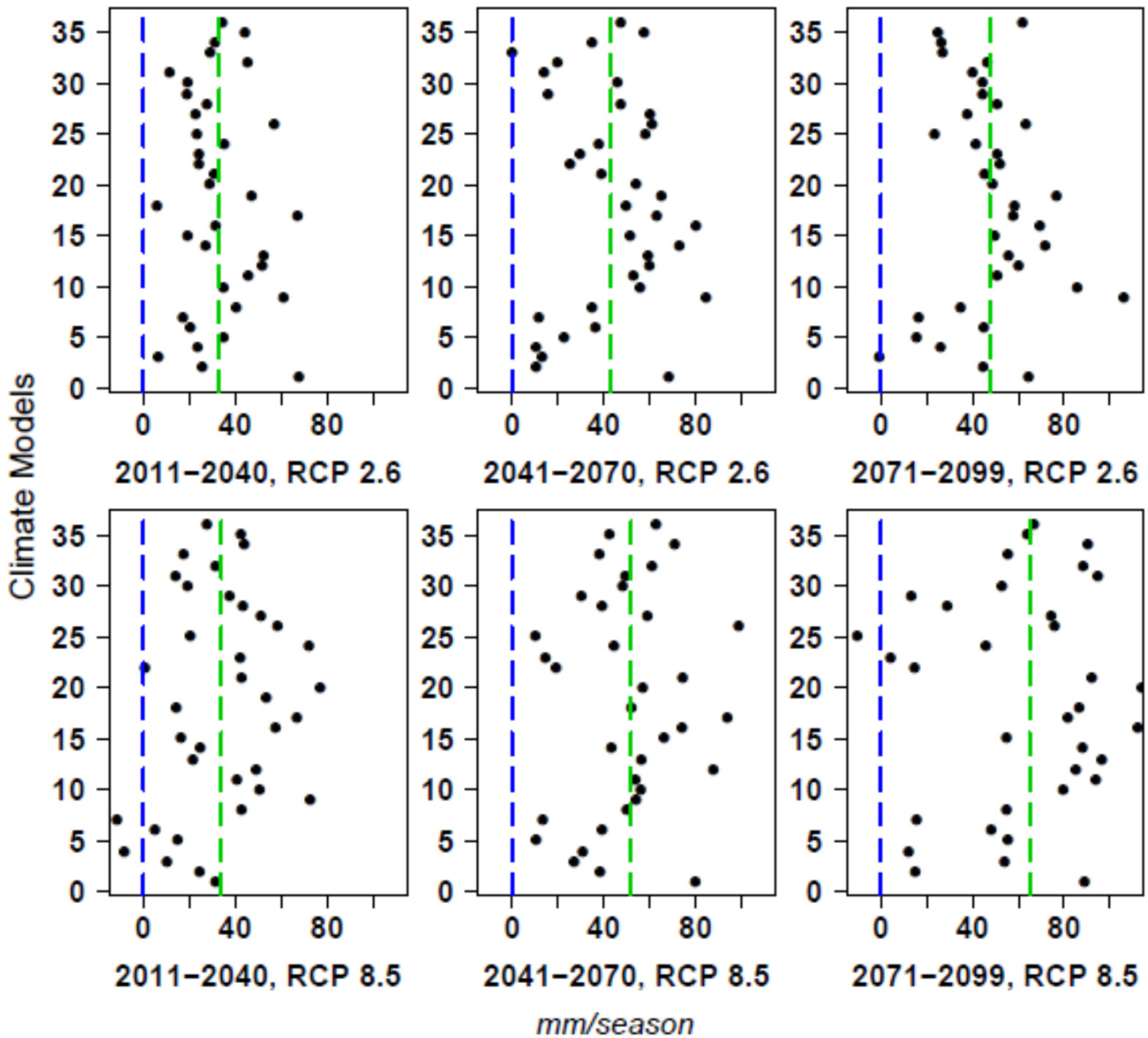

St. Mary's River @ Willshire
March 9, 2014


Field near Tiffin, OH
March 13, 2014
(From Tom Green)

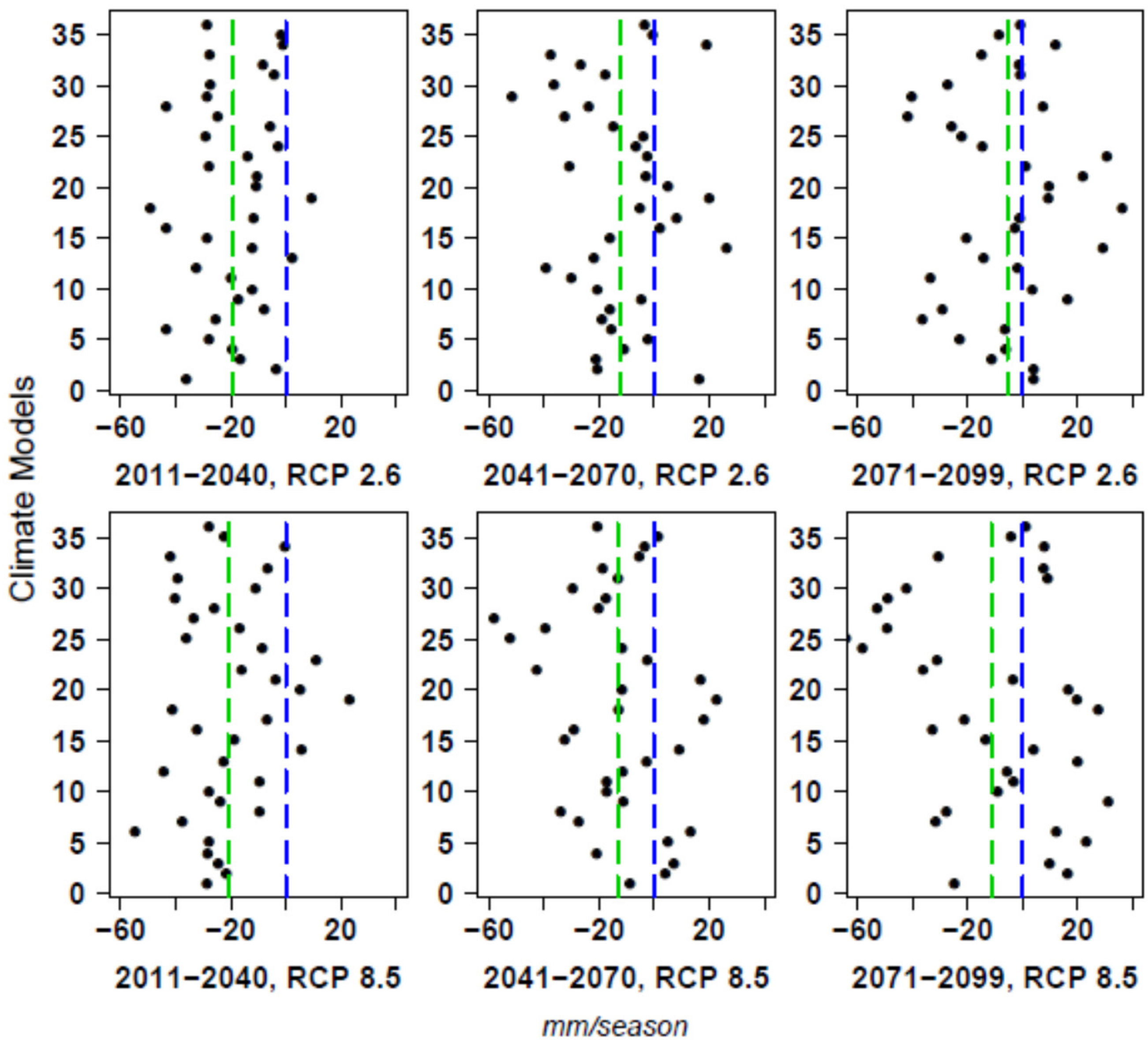
Summer Temp. Predictions



Spring Precip. Predictions

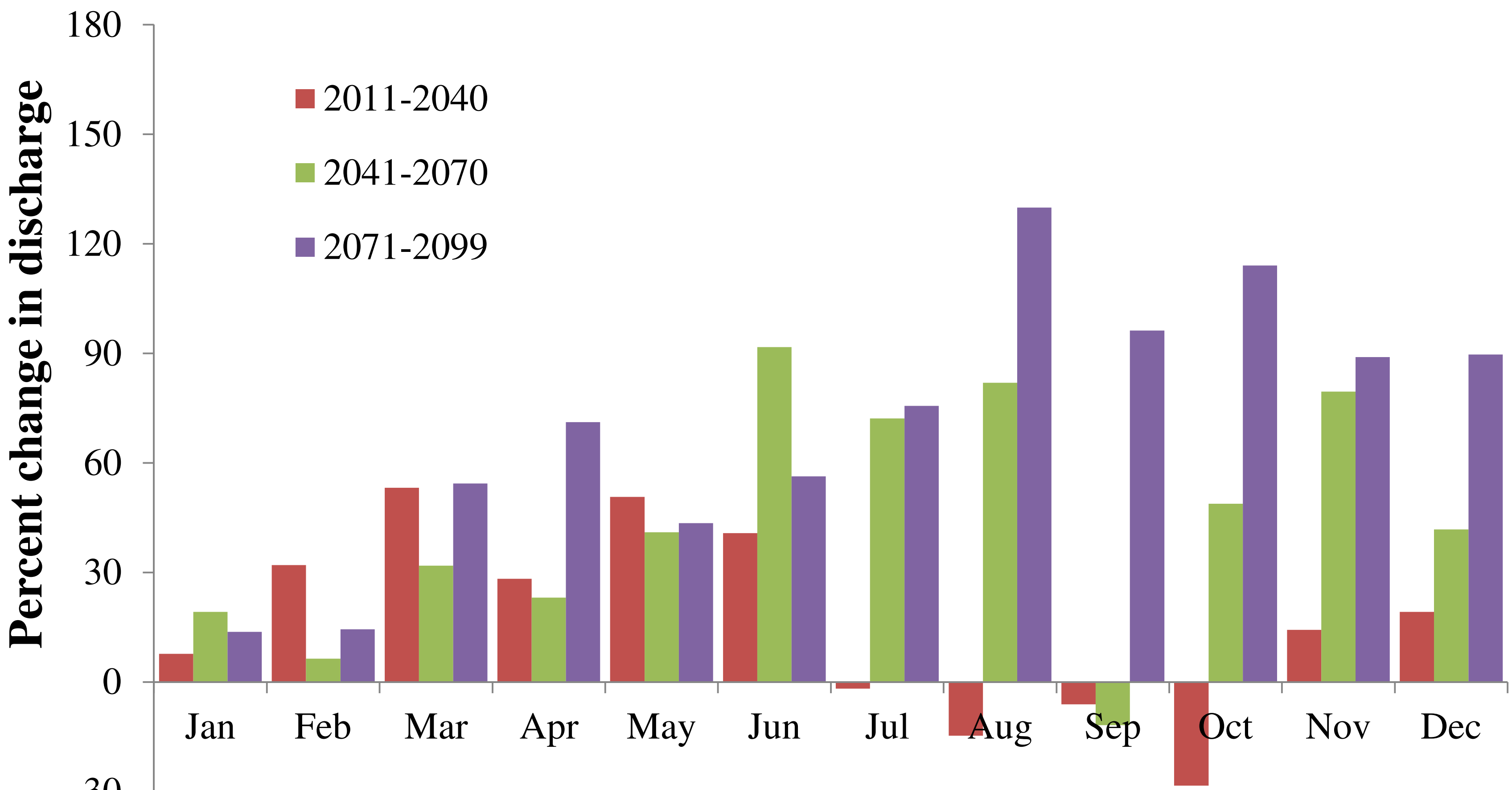


Summer Precip. Predictions



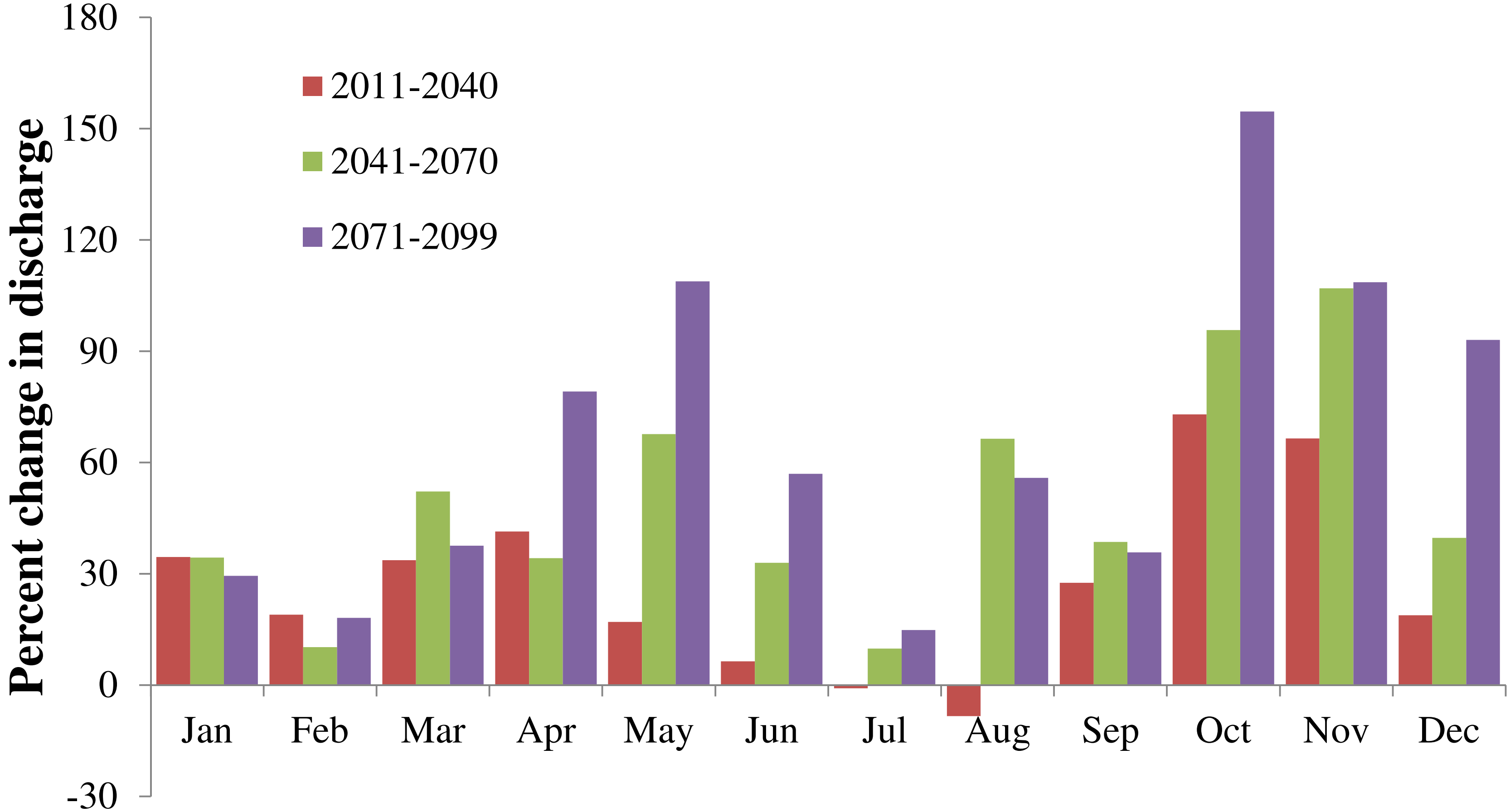
Maumee Discharge Projections

(bcc-csm1-1, 2.6)



Maumee Discharge Projections

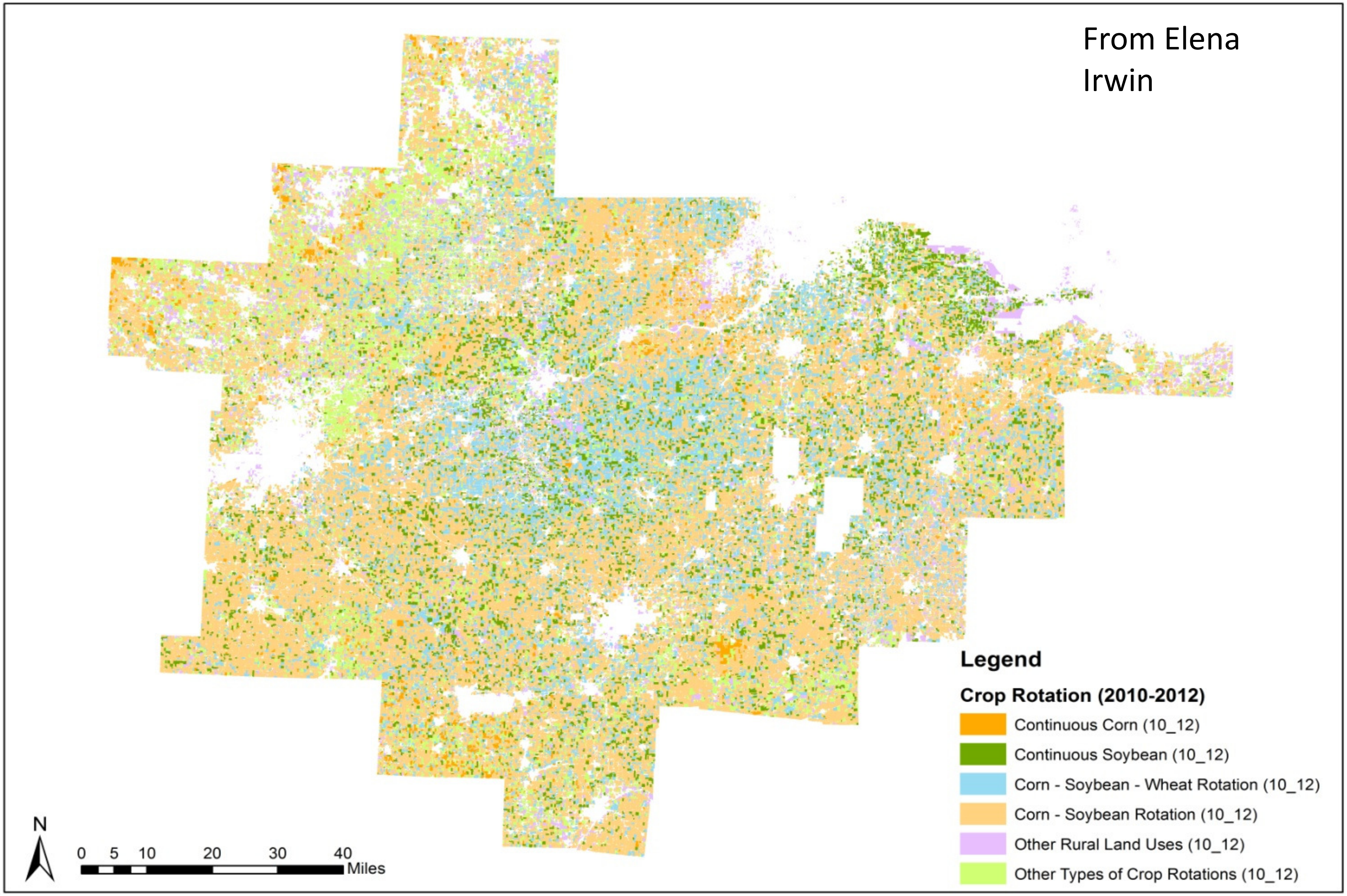
(bcc-csm1-1, 8.5)



SWAT Issues: Spatial Resolution

- SWAT modeling scale >> management scale
- Management decisions @ parcel level ~ 0.2km^2.
- Current SWAT scale ~ 5 km^2 (3000 HRUs for 17,000 km^2).
- To match parcel level, need ~ 142,000 HRUs.

Parcel-level crop rotation (2010-2012)



SWAT Issues: Crop Schedules

- How to simulate yearly schedules of planting, harvesting, tilling, fert. apps?
- High variability in farming practices.
- Must simplify, but need to be realistic.
- How to model switches to new schedules over time?
- How handled in past models?
- Future goal to evaluate ability of better timing of fertlizer app. to reduce P runoff and discharge from Maumee.

SWAT Issues: Crop Schedules

Management Practice in Lake Erie Watershed	Percentage
Broadcast phosphorus with no tillage	36%
Broadcast phosphorus and incorporate with tillage, or use strip tillage	34%
Incorporate phosphorus with the planter as starter	30%

Based on survey results from Greg LaBarge (OSU Extension)

Rotation	Percentage of Rural Acreage
Corn-Soybean	35.1%
Corn-Soybean-Wheat	32.6%
Corn-Soybean-Wheat-Hay	7.6%
Continuous Soybean	6.4%
Soybean-Wheat	2.6%
Continuous Corn	1.2%
Corn-Wheat	0.1%
Other Rural	14.6%

These four rotations will be included in our model

Based on land use aggregation data from Dr. Irwin's lab

Four rotations to be used:

- Corn-Soybean
- Corn-Soybean-Wheat
- Corn-Soybean-Wheat-Hay
- Continuous Soybean

Three phosphorus management plans to be used:

- Broadcast in autumn with no tillage
- Broadcast in autumn with tillage
- Incorporation in spring with planter

This means a total of **twelve schedules** need to be created. These schedules can be adjusted to start with different crops, based on “year 1” land use.
i.e., if the model begins in 2007, implement schedules starting with corn planted in year 1 for Corn HRUs in 2007 land use data. For soybean HRUs, modify the schedule to begin with soybeans. For example, the rotation for a 2007 Soybean HRU will go soybean-wheat-corn instead of corn-soybean-wheat.

Fertilizer application is derived from Tri-State recommendations and advice from OSU extension agents and OEPA employees. Our model uses 28_0_0 and 46_0_0 formulations for nitrogen application, and MAP for phosphorus application. Although over-application of manure may occur in the watershed, only chemical fertilizers are used in the model and no over-application done.

SWAT does not account for potassium in plant growth or nutrient modeling, so no potash is added.

Challenges

- These rotations are only approximations based on several years of data. A "corn-soybean-wheat" rotation on a given parcel may in actuality look like: soybean-corn-wheat-corn-soybean-soybean-wheat-corn
- Due to the simplification of the rotations, ratios of each crop can become distorted. For example, about 50% of the row crops on any given year should be soybean. Due to the large number of Soybean HRUs in year 1, a large fraction of the row crops in year 2 switch to "wheat" in the corn-soybean-wheat and corn-soybean-wheat-hay rotations. The percentage of wheat in the watershed becomes inflated, and the percentage of soybean is artificially lowered.
  - To counter this, the percentage of "continuous soybean" will need to be increased and the percentage of "corn-soybean-wheat" and "corn-soybean-wheat-hay" rotations will need to be lowered.

Example 1: Corn-Soybean Rotation, Broadcast fertilizer WITH tillage

- Because only three of the four rotations include corn, the percentages must be recalculated. The corn-soybean rotation is only 35.1% of the *total* agricultural acreage, but 47% of the acreage *that includes corn* is on this rotation.
- In practice, MAP fertilizer is generally added only once every two years on this rotation

9-yr_C,S_fall_till_base		34% of 47% of Corn HRUs (16.0% of Corn HRUs)			
CORN-SOYBEAN					
year	date	operation	notes		
1	1-May	fertilizer (Nitrogen only)	122 kg/ha	28_0_0	0 at surface
1	1-May	plant corn			
1	1-Jun	Sidedress Nitrogen	400 kg/ha	28_0_0	0 at surface
1	26-Oct	harvest and kill			
2	10-May	plant soybean			
2	25-Sep	harvest and kill			
2	16-Oct	fertilizer	195 kg/ha	MAP	0.95 at surface
2	23-Oct	tillage	field cultivator		
3	1-May	fertilizer (Nitrogen only)	103 kg/ha	28_0_0	0 at surface
3	1-May	plant corn			

Example 2: Corn-Soybean Rotation, Broadcast fertilizer WITHOUT tillage after fertilizer application

- In other rotations, tillage may be necessary (e.g. corn-soybean-wheat), but in this scenario it would occur *before* fertilizer application

9-yr_C,S_fall_NOtill_base		36% of 47% of Corn HRUs (16.9% of corn HRUs)			
CORN-SOYBEAN					
year	date	operation	notes		
1	9-May	fertilizer (Nitrogen only)	122 kg/ha	28_0_0	0 at surface
1	9-May	plant corn			
1	6-Jun	Sidedress Nitrogen	400 kg/ha	28_0_0	0 at surface
1	31-Oct	harvest and kill			
2	10-May	plant soybean			
2	25-Sep	harvest and kill			
2	16-Oct	fertilizer	195 kg/ha	MAP	0.95 at surface
3	9-May	fertilizer (Nitrogen only)	122 kg/ha	28_0_0	0 at surface
3	9-May	plant corn			

Example 3: Corn-Soybean Rotation, Fertilizer incorporated in spring as starter

- The Tri-State recommended amounts of nitrogen and phosphorus cannot be achieved using only MAP (without over-applying phosphorus), so additional nitrogen is added during planting (28 kg/ha of 46_0_0).

9-yr_C,S_spring_base		30% of 47% Corn HRU (14.1% of Corn HRUs)			
CORN-SOYBEAN					
year	date	operation	notes		
1	24-Apr	tillage	coulter chisel		
1	29-Apr	tillage	field cultivator		
1	9-May	fertilizer	195 kg/ha	MAP	0 at surface
1	9-May	fertilizer (Nitrogen)	28 kg/ha	46_0_0	0 at surface
1	9-May	plant corn			
1	6-Jun	Sidedress Nitrogen	400 kg ha	28_0_0	0 at surface
1	31-Oct	harvest and kill			
2	10-May	plant soybean			
2	25-Sep	harvest and kill			
3	24-Apr	tillage	coulter chisel		
3	29-Apr	tillage	field cultivator		
3	9-May	fertilizer	195 kg/ha	MAP	0 at surface
3	9-May	fertilizer (Nitrogen)	19 kg/ha	46_0_0	0 at surface
3	9-May	plant corn			