Watershed modeling to assess the sensitivity of streamflow, nutrient and sediment loads to potential climate change and urban development in 20 U.S. watersheds

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Authors: Thomas Johnson[1], Jon Butcher[2], Chris Weaver[3], Daniel Nover[3], Jonathan Witt[3], Andrew Parker[2]

1. USEPA Office of Research and Development (johnson.thomas@epa.gov); 2. Tetra Tech, Inc., Fairfax, VA; 3. USEPA Office of Research and Development

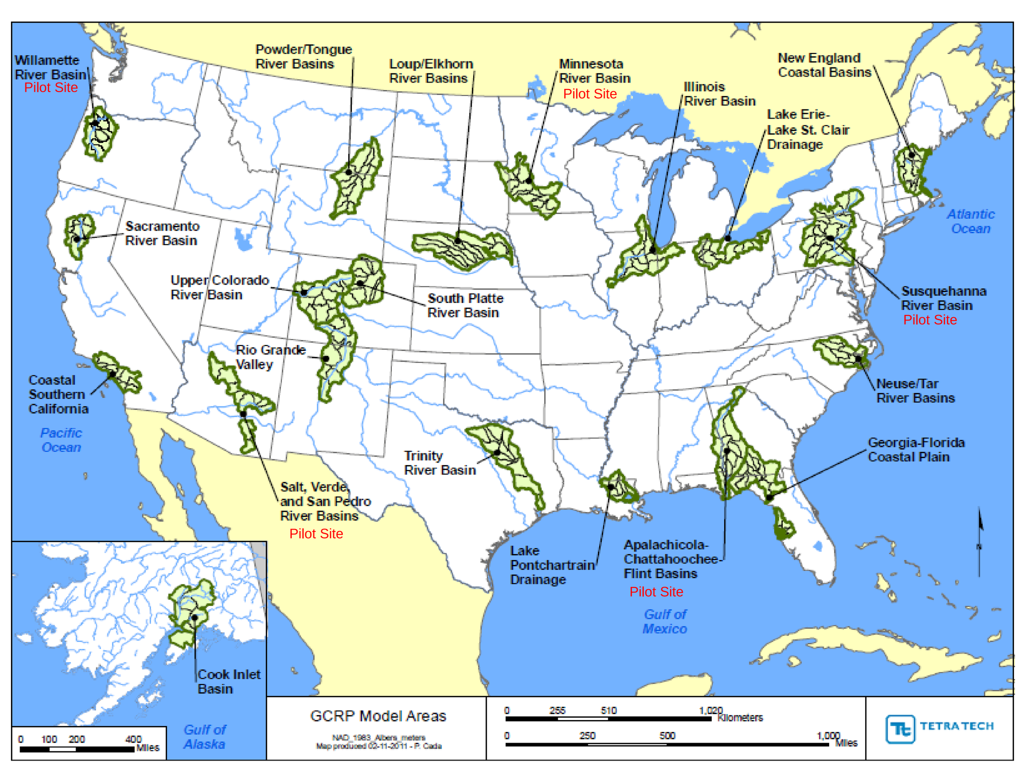
Purpose

- Assess the sensitivity of U.S. streamflow, nutrient (N and P), and sediment loading to climate change across a range of plausible mid-21st Century climate futures
- Potential interactions with urban development
- Methodological challenges associated with integrating existing tools (e.g., climate models, watershed models) and datasets to address these scientific questions

Modeling Approach

- Daily simulations of streamflow, N, P, sediment for historical (1970-2000) and future (2041-2070) periods
- Model segmentation within larger watersheds about HUC8 (~ 1000-2000 sq. miles)
- Climate change scenarios implemented using a change factor approach
- In all 20 watersheds:
  - run SWAT model at daily time step
  - 6 climate change scenarios (NARCCAP; SRES A2 emission scenario)
  - 2 land development scenarios, current and 2050 (EPA ICLUS)
- In subset of 5 "pilot" watersheds:
  - run HSPF model with same set of scenarios as SWAT
  - 8 additional climate change scenarios with both models (4 from BCSD; 4 from parent GCM runs)
  - evaluate sensitivity of simulation results to method of downscaling climate data and different watershed models

Study Areas



Study sites represent a range of geographic, hydrologic, and climatic characteristics

Scenarios

Climate scenarios based on dynamically downscaled (50m) data from the North American Regional Climate Change Assessment Program (NARCCAP), and bias-corrected and statistically downscaled (BCSD) data from the archive developed by Bureau of Reclamation/Santa Clara University/Lawrence Livermore.

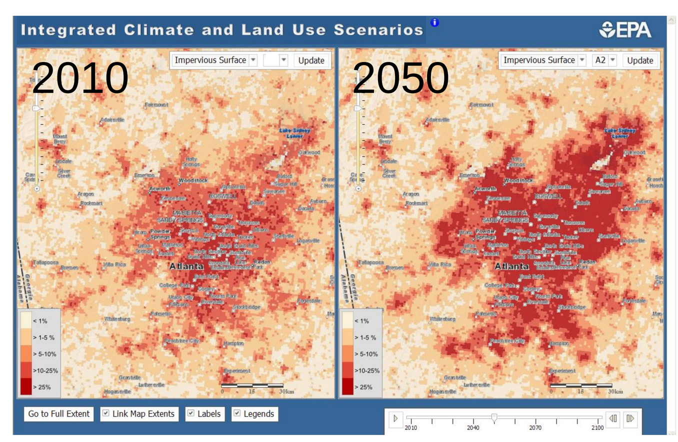
	GCM			
	CGCM3	HADCM3	GFDL	CCSM
Downscaling Approach or RCM	None	None	None	None
	Statistical (BCSD)	Statistical * (BCSD)	Statistical (BCSD)	Statistical * (BCSD)
	CRCM (NARCCAP)	HRM3 (NARCCAP)	RCM3 (NARCCAP)	WRFP (NARCCAP)
	RCM3 (NARCCAP)		GFDL hires (NARCCAP)	

CGCM3: Third Generation Coupled GCM
HADCM3: Hadley Centre Coupled Model, v.3
GFDL: Geophysical Fluid Dynamics Lab. GCM
CCSM: Community Climate System Model

CRCM: Canadian Regional Climate Model
RCM3: Regional Climate Model, version 3
HRM3: Hadley Region Model 3
WRFP: Weather Research and Forecasting Mod
GFDL hires: Geophysical Fluid Dynamics Laboratory 50-km global atmospheric timeslice

- Not same run / from same family

Urban and residential development scenarios from EPA's Integrated Climate and Land Use Scenarios (ICLUS) project.



National scale scenarios of changes in urban and developed lands consistent with IPCC SRES emissions storylines

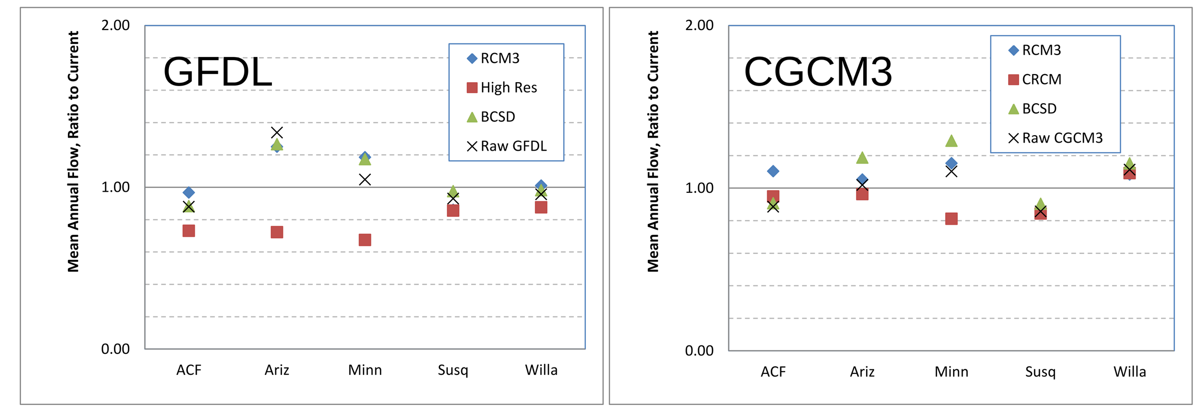
Developed based on county level population changes distributed spatially within counties using the Spatially Explicit Regional Growth Model (SERGoM).

SWAT Calibration/Validation

Study Area	Initial Cal/Val Sub-watershed	Total Flow Cal/Val (NSE, Daily)	Total Flow Cal/Val (% Error)	TSS Load Cal/Val (% Error)	TP Load Cal/Val (% Error)	TN Load Cal/Val (% Error)
Apalachicola-Chattahoo.-Flint	Upper Flint River	0.62/0.56	7.28/3.33	-9/17	-50/-30	-18/9
Coastal Southern California Basins	Santa Ana River	0.63/0.59	3.71/1.61	19/NA	-14.7/NA	-5.5/NA
Cook Inlet Basin	Kenai River	0.68/0.55	-18.96/19.5	66.4/64.1	83.2/82.2	57.3/50.4
Georgia-Florida Coastal Plain	Ochlockonee River	0.71/0.8	4.25/-5.54	9.5/-6.6	-7.4/-5.8	-8/-5
Illinois River Basin	Iroquois River	0.70/0.67	-16.99/-2.9	38/39	5/-1	56/60
Lake Erie-Lake St. Clair	Lake Erie-St. Clair Basin	0.61/0.62	-3.32/-13.4	67.9/69.8	23.9/-12.5	35.8/13.7
Lake Pontchartrain	Amite River	0.79/0.69	-1.61/-0.93	9.2/NA	2.4/NA	-8.9/NA
Loup/Elkhorn River Basin	Elkhorn River	0.42/0.52	-2.59/-8.81	59.6/66.8	24.2/34.9	28.1/18.1
Minnesota River Basin	Cottonwood River	0.79/0.74	-5.41/-0.84	9.2/9	9.3/-21.6	-8.9/-1.3
Neuse/Tar River Basins	Contentnea Creek	0.68/0.64	-3.98/-1.18	-19.9/9.9	15.9/5.3	-5.6/5.3
New England Coastal Basins	Saco River	0.61/0.76	1.08/0.67	-9/3.2	9.6/-11.5	27.5/26.3
Powder/Tongue River Basin	Tongue River	0.72/0.70	9.26/-9.95	-21.8/-3.4	8.8/35.1	3.9/31.5
Rio Grande Valley	Saguache Creek	0.47/0.07	-4.92/32.99	57.3/41	-46.9/-653	-28.3/-909
Sacramento River Basin	Sacramento River	0.75/0.57	10.23/10.06	-2/-55	-8/-33	-135/-156
Salt, Verde, and San Pedro	Verde River	0.03/-1	-2.46/5.68	16.9/-42.6	83.5/31.4	-14.4/-15.9
South Platte River Basin	South Platte River	0.74/0.52	9.82/-16.3	86.6/	-14/NA	6.1/NA
Susquehanna River Basin	Raystown Br. of the Juniata	0.29/0.42	-5.41/16.3	-10.1/-33.6	-0.5/-9.2	28.6/43.9
Trinity River Basin	Trinity River	0.62/0.47	-6.88/0.7	9.2/-17.4	3/-21.58	-3.8/-31.9
Upper Colorado River Basin	Colorado River	0.83/0.78	8.18/0.93	0.4/NA	47.4/NA	15.1/NA
Willamette River Basin	Tualatin River	0.49/0.39	-4.76/-12.1	-12/-7	-114/-105	-72/-66

Comparison of Methods and Models

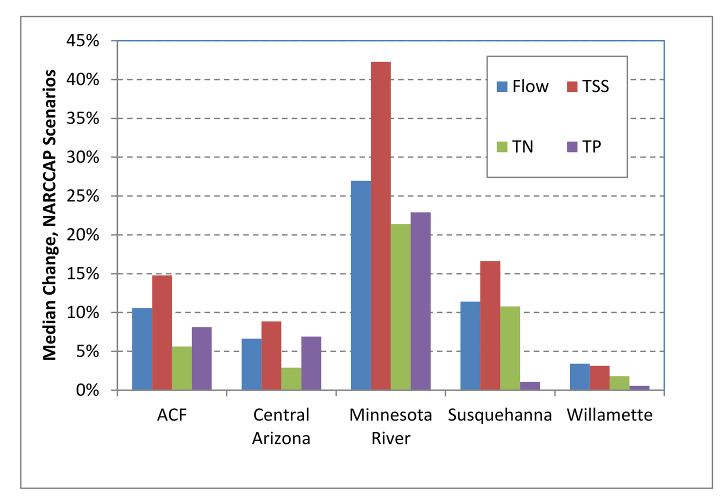
SWAT simulations for mean annual flow using different downscaled (NARCCAP, BCSD) and non-downscaled GCM projections from GFDL and CGCM3 GCMs



SWAT simulated changes in mean annual flow in response to climate change and urban development (across all HUC 8 subwatersheds in the study area)

	Flow Response to Climate Change		Flow Response to Urbanization	
	Minimum	Maximum	Minimum	Maximum
Apalachicola-Chattahoochee-Flint Basins	-45.73%	27.69%	0.00%	3.70%
Salt, Verde, and San Pedro River Basins	-35.29%	152.52%	0.00%	1.48%
Loup/Elkhorn River Basin	-77.45%	20.69%	0.00%	0.27%
Lake Erie Drainages	-22.89%	21.12%	0.00%	1.84%
Georgia-Florida Coastal Plain	-39.73%	37.17%	0.01%	7.36%
Illinois River Basin	-23.05%	18.95%	0.00%	11.90%
Minnesota River Basin	-20.61%	85.38%	0.00%	0.19%
New England Coastal Basins	-12.55%	9.16%	0.01%	0.76%
Lake Pontchartrain Drainage	-24.75%	21.82%	0.00%	1.24%
Rio Grande Valley	-38.80%	11.06%	-0.11%	0.08%
Sacramento River Basin	-20.79%	0.04%	-0.03%	0.47%
Coastal Southern California Basins	-26.91%	21.08%	1.66%	9.50%
South Platte River Basin	-60.45%	-0.68%	-1.00%	6.87%
Susquehanna River Basin	-23.80%	25.79%	0.00%	0.23%
Tar and Neuse River Basins	-13.65%	61.83%	0.28%	4.31%
Trinity River Basin	-60.57%	40.43%	6.39%	34.91%
Upper Colorado River Basin	-20.21%	5.58%	-0.38%	0.47%
Willamette River Basin	-17.51%	1.31%	-1.18%	0.00%
Powder/Tongue River Basins	-86.54%	-76.33%	0.00%	0.00%

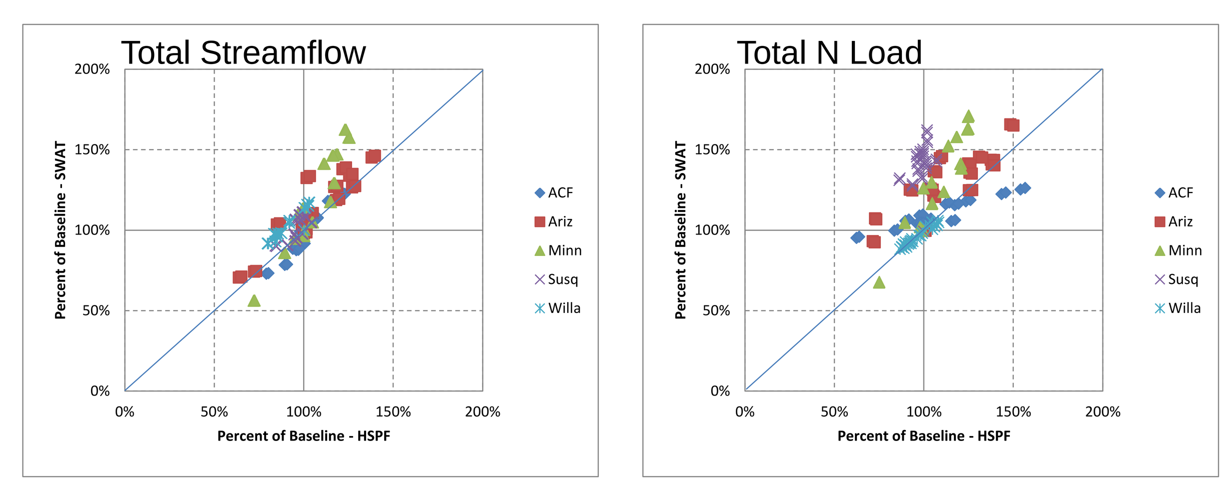
Changes in SWAT projected changes with representation of increased CO_2 (($withCO_2 - noCO_2$)/$noCO_2$)



Current CO_2 = 369 ppmv

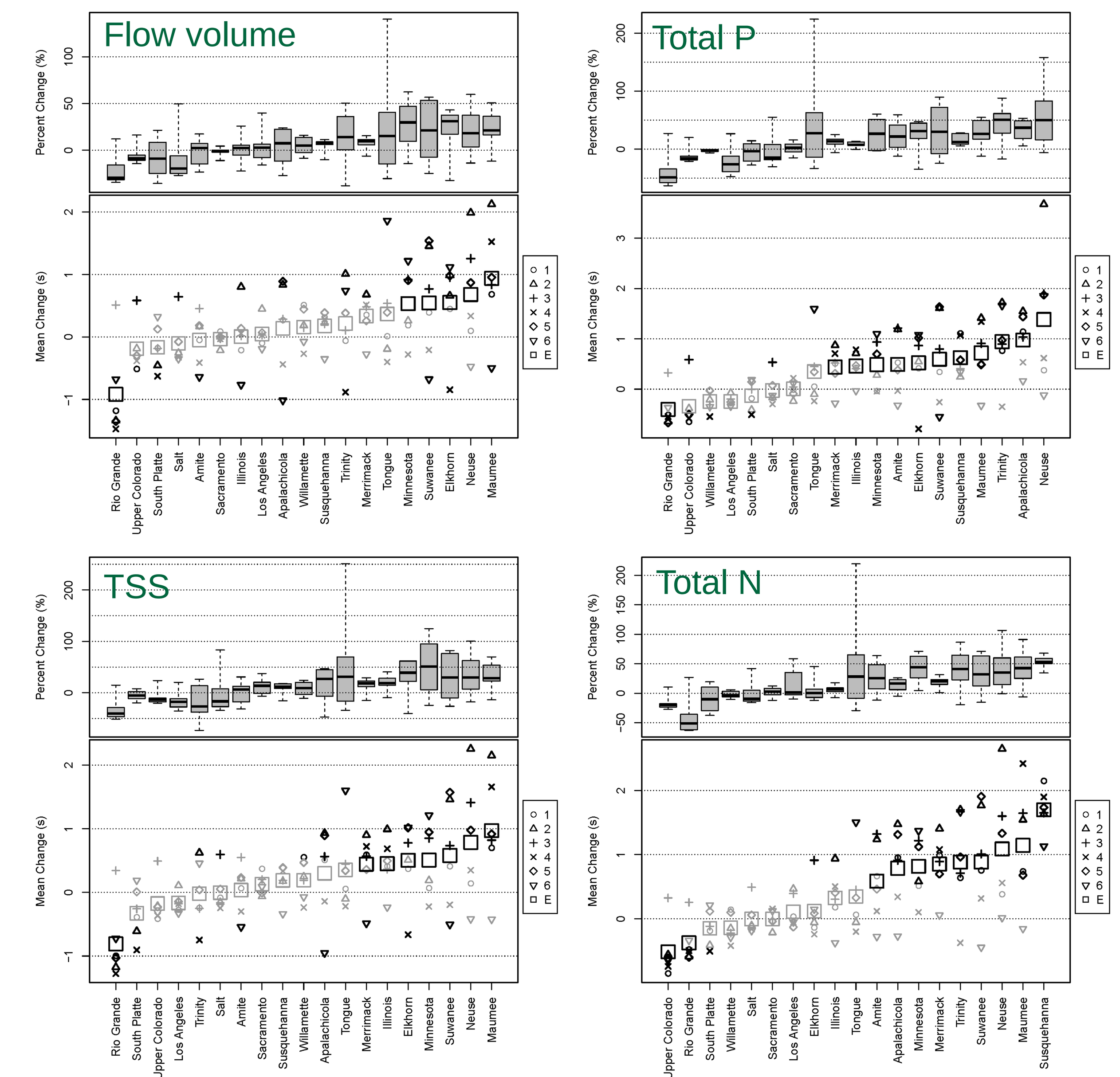
Future CO_2 (A2, 2050) = 533 ppmv

SWAT and HSPF simulated changes in total flow and nitrogen load in pilot sites (relative to current conditions)



Regional Variability

SWAT simulated changes in streamflow, N, P and TSS loading for mid-21[st] century climate change (6 NARCCAP scenarios). In each figure, the top panel shows percent change relative to baseline, and bottom panel shows the change normalized by the standard deviation of baseline values. Bold symbols indicate change is significant from baseline (p<0.05).



Conclusions

- High variability in simulated responses to potential mid-21st century climatic conditions; span a wide range and in many cases do not agree in the direction of change
- Simulations sensitive to methodological choices such as different approaches for downscaling global climate change simulations and use of different watershed models.
- Simulated responses to urban development scenarios small at the spatial scale of this study; larger effects likely at finer scales
- Results are conditional on methods and scenarios used in this study. Scenarios represent a plausible range of changes but are not comprehensive of all possible futures.

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