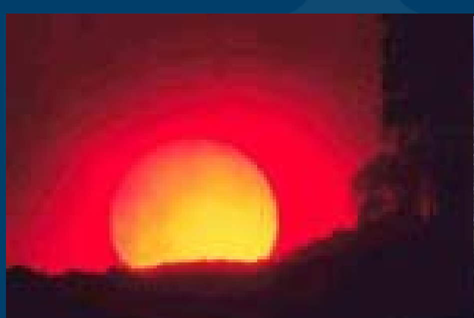
Water Quality and Aquatic Ecosystem Sensitivity to Climate Change: Highlights of EPA ORD NCEA Projects

Thomas Johnson
US EPA, ORD Global Change Research Program

STAR Progress Meeting
September 21, 2011




Overview

ORD NCEA's Scenarios Work

- Supports assessments of flow and water quality changes, impacts on aquatic ecosystems, and others

Approaches and Methodologies for Impacts, Adaptation, and Vulnerability

- Examples of the type of work we do: Biomonitoring, Climate Ready Estuaries, Robust Decision Making

National Climate Assessment

Future Directions

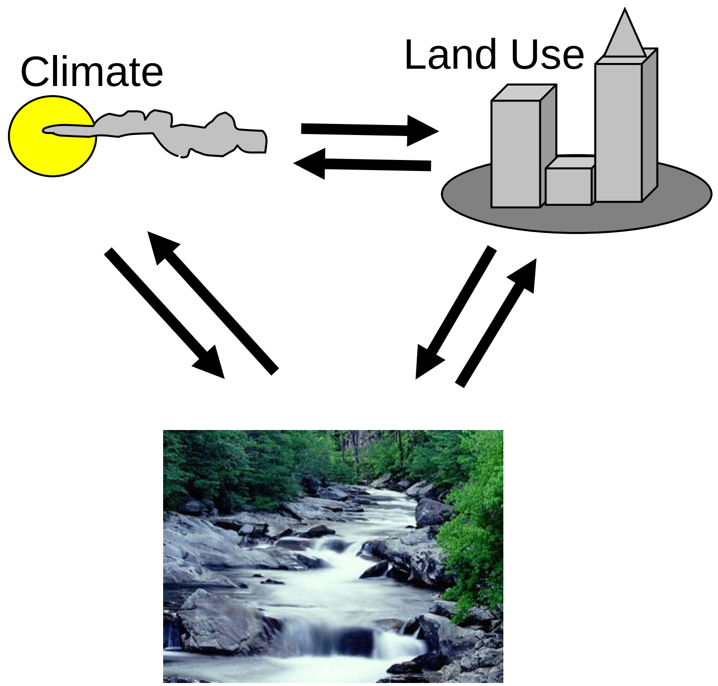
The “20 watershed” modeling project

<u>Goal to assess:</u>

• 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

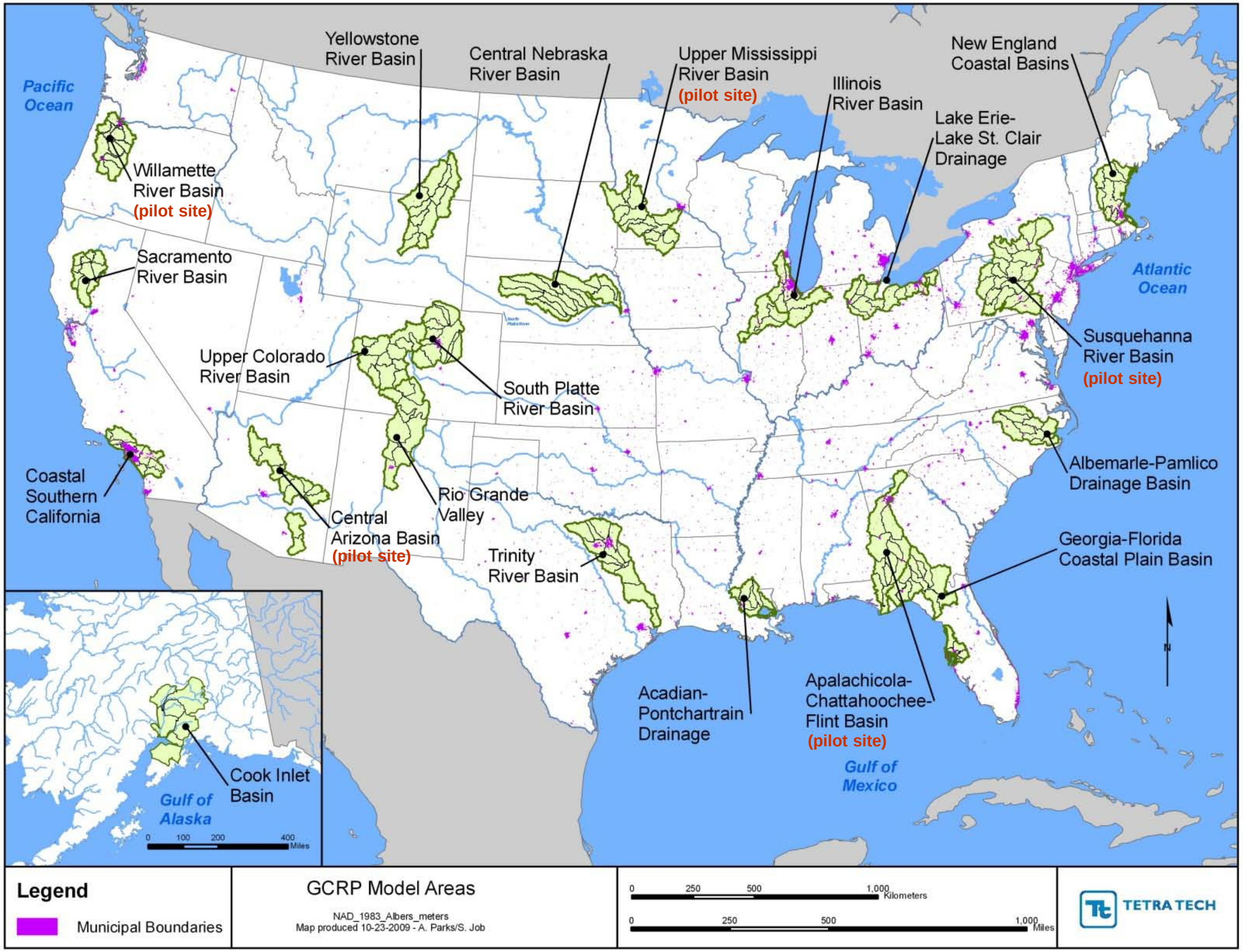
• Potential interactions of climate change with increasing urbanization in these watersheds

• Methodological challenges associated with integrating existing tools (e.g., climate models, land-use models, watershed models) and datasets to address these scientific questions



Hydrology, Ecosystems,
Human Communities

20 Watersheds – Study Sites



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Modeling Approach

Daily simulations of streamflow, N, P, sediment for historical (1970-2000) and future (2040-2070) periods

Spatial resolution about HUC8 (~ 1000-2000 sq. miles)

<u>In 5 pilot watersheds:</u>

- Use 2 watershed models, HSPF and SWAT
    - 14 climate change scenarios (NARCCAP, raw GCM, BCSD; A2 emissions scenario)
    - 2 land-use scenarios, current and future (EPA ICLUS)
- Simulated effects of climate change, land-use change, coupled C-L change
- Sensitivity studies to assess influence of different methods of downscaling

<u>In 15 non-pilot watersheds:</u>

- Use 1 watershed model, SWAT
    - 6 climate change scenarios (NARCCAP; A2 emissions scenario)
    - 2 land-use scenarios, current and future (EPA ICLUS)
- Simulated effects of climate change, land-use change, coupled C-L change

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Climate change scenarios

Climate Change Scenarios Evaluated

Scenario #	Climate Model(s)
NARCCAP scenarios	
1	CRCM_CGCM3
2	HRM3_HadCM3
3	RCM3_GFDL
4	GFDL high res_GFDL
5	RCM3_CGCM3
6	WRFP_CCSM
Driving GCMs of the NARCCAP scenarios (i.e., no downscaling)	
7	CGCM3
8	HADCM3
9	GFDL
10	CCSM
Bureau of Reclamation BCSD statistically downscaled scenarios	
11	CGCM3
12	HADCM3
13	GFDL
14	CCSM

Representation of climate scenarios:

- GCM/RCM projections interpolated to NCDC weather stations

- "delta change" method to create hydro model inputs

- PET calculated using Penman-Monteith

Climate Change Scenarios:
North American Regional Climate Change Assessment Program (NARCCAP)
http://www.narccap.ucar.edu/

Dynamically downscaled

6 international modeling teams (Partner: NCAR)

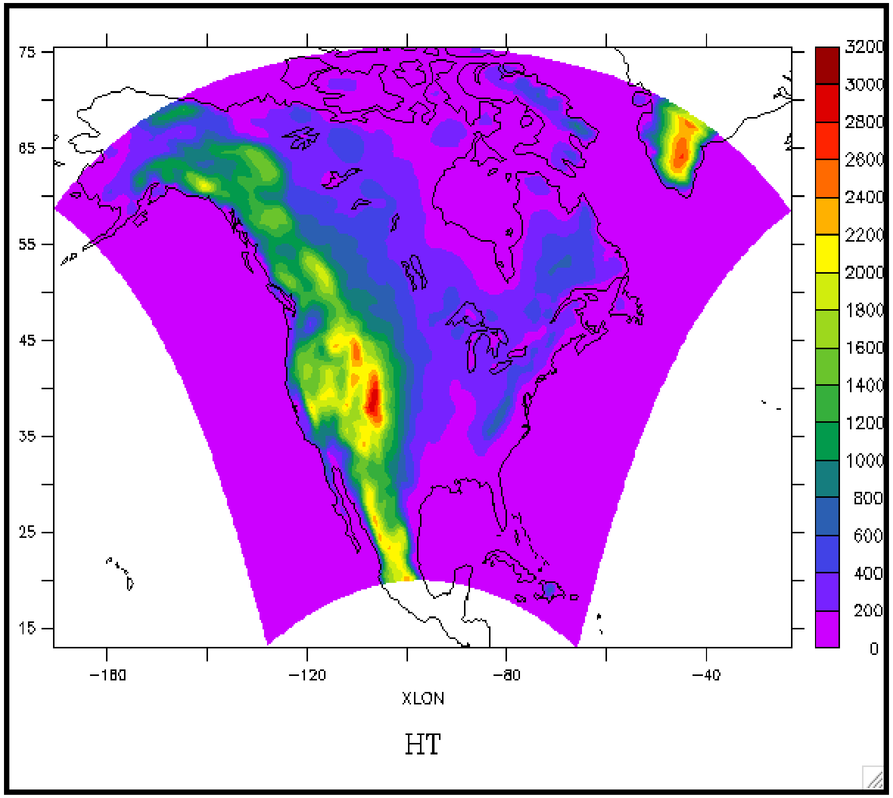
IPCC A2 emission storyline

Future: 2040-2070
Historical: 1970-2000

Spatial grid: 50-km

Time freq: 3-hourly

Change in average amount, seasonality, intensity, extremes for T, P, winds, clouds, etc.



Climate Change Scenarios:
Bias Corrected and Statistically Downscaled WCRP CMIP3 Climate Projections

http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html

Statistically downscaled

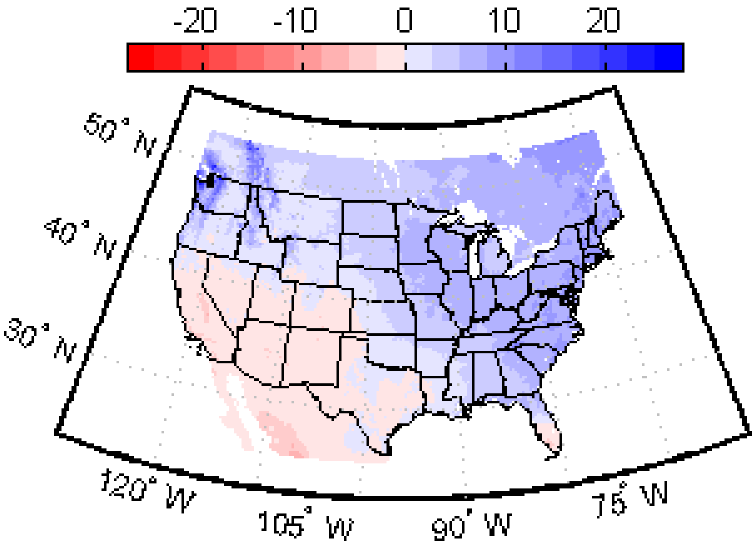
All IPCC modeling groups (AR4)

Time Period: 1950-2100

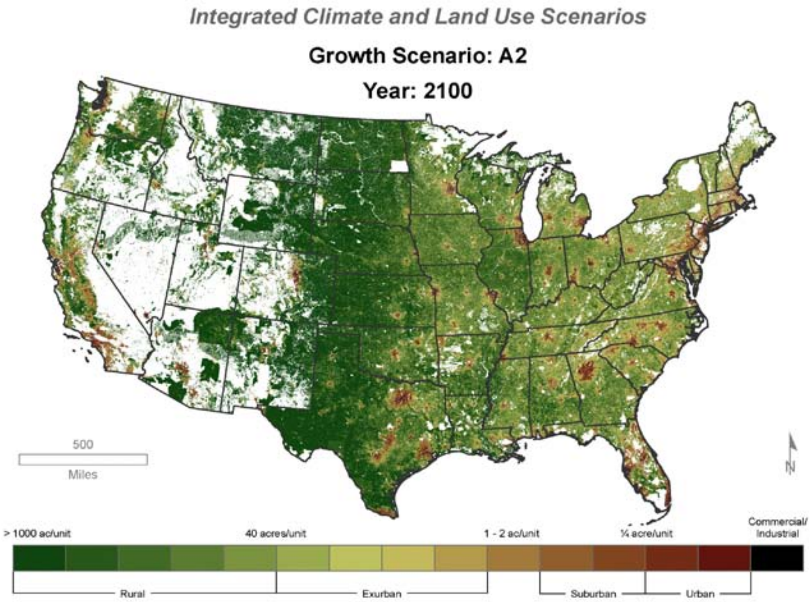
Spatial grid: 1/8-degree

Time freq: Monthly-mean

Temp and precip only



Land-use change scenarios



Representation of land-use scenarios:

- 2001 NLCD

- EPA ICLUS; projected 2050 land-use change (developed land)

Land-use Change Scenarios:

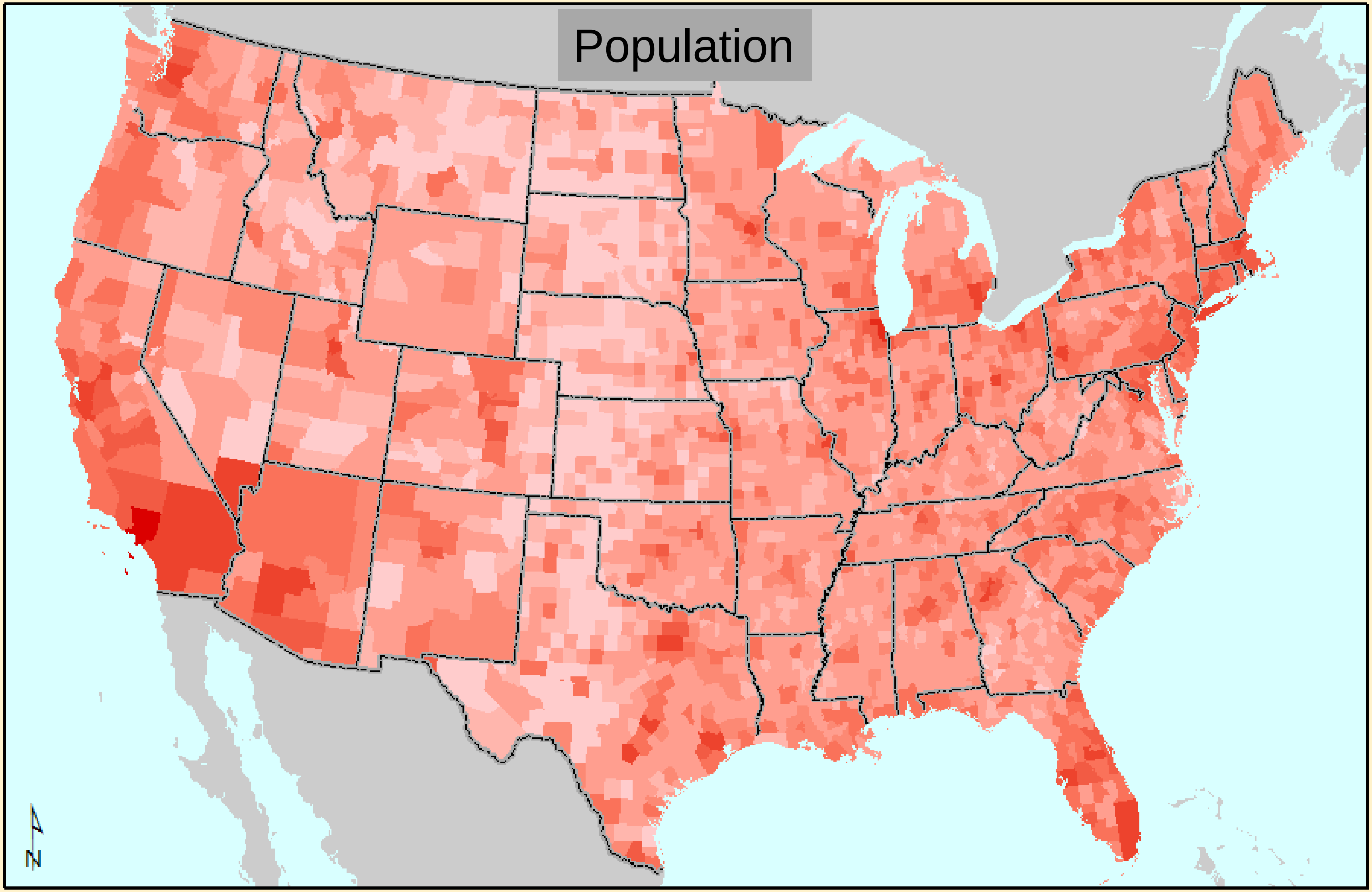
EPA Integrated Climate and Land-use Change Scenarios (ICLUS)

- Housing density (100m res) and impervious cover (1km res)

- Five scenarios,
    - 4 consistent with the different assumptions underlying the IPCC SRES A1, A2, B1, B2 IPCC greenhouse gas storylines
    - 1 arbitrary “middle” scenario

- Coverage for the conterminous US; from 2000 to 2100

- Also working on GIS tools to generate custom scenarios



Thousands of People Per County

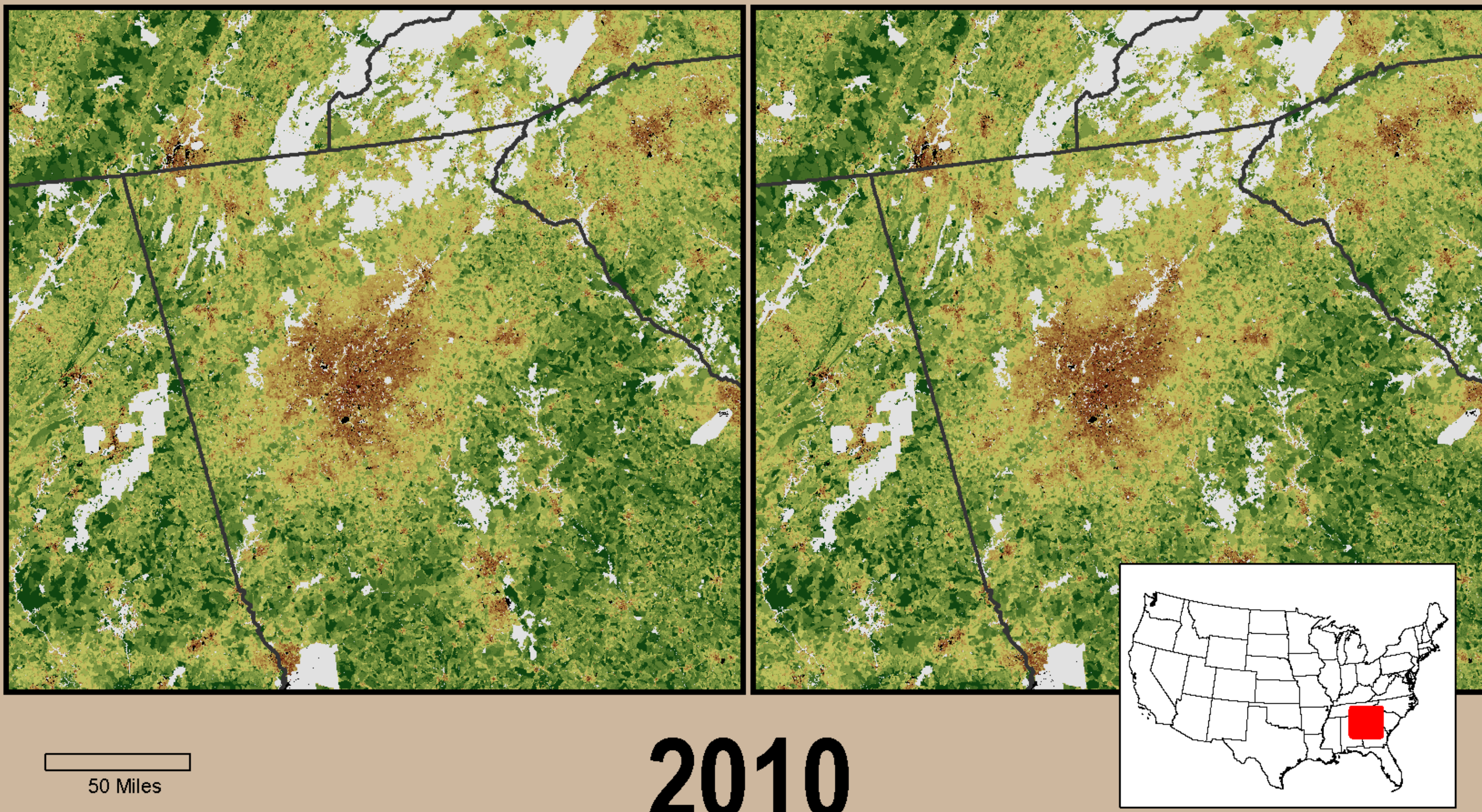
- <= 5
- 5 - 10
- 10 - 50
- 50 - 100
- 100 - 500
- 500 - 1,000
- 1,000 - 5,000
- 5,000 - 10,000
- > 10,000

Integrated Climate and Land-Use Scenarios (ICLUS)
Population Projections for 2010

Albers Projection
Central Meridian: -96
1st Std Parallel: 20
2nd Std Parallel: 60
Latitude of Origin: 40

500 Miles

A2 Housing Density B1



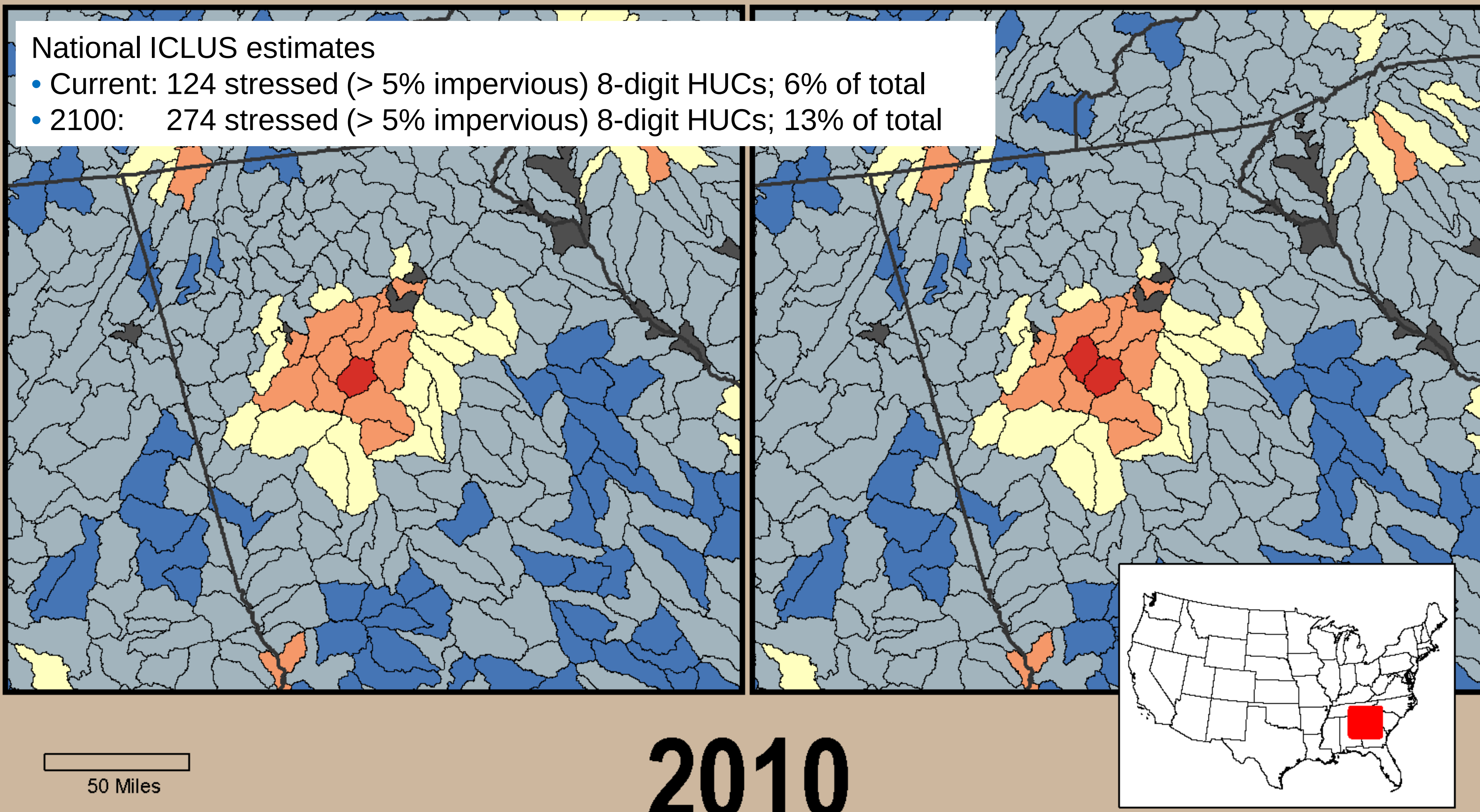
50 Miles

2010

> 1000 ac/unit
40 acres/unit
1 - 2 ac/unit
¼ acre/unit
Commercial/ Industrial

Rural
Exurban
Suburban
Urban

A2 Impervious Cover B1



2010

Unstressed	Lightly Stressed	Stressed	Impacted	Damaged
< 1%	1 - 5%	>5 - 10%	>10 - 25%	>25%

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Results - 5 Pilot Sites

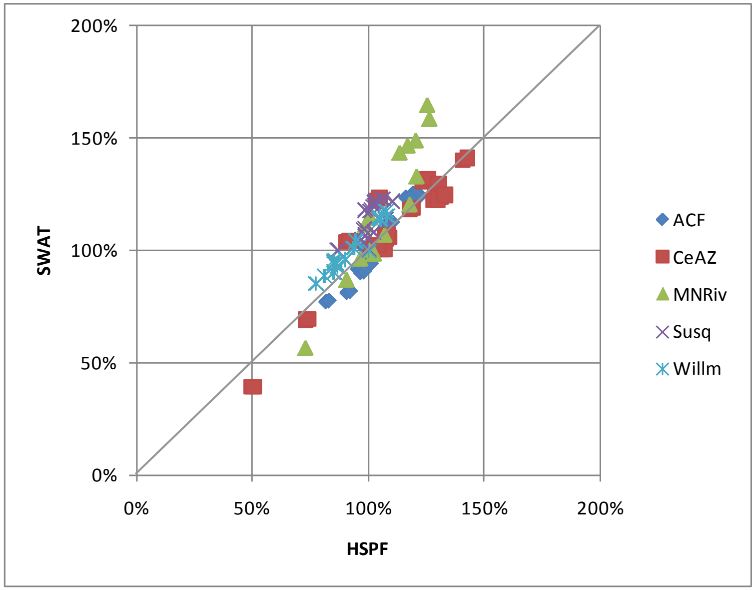
Results illustrate key methodological issues, sensitivities, uncertainties associated with CC-hydrologic impacts assessments:

1. Sensitivity of simulated changes to the watershed model used;
2. Sensitivity of simulated changes to climate model and downscaling approach used;
3. Interaction of climate change with other key forcing factors:
   a. Urban development
   b. Change in atmospheric CO2 concentration

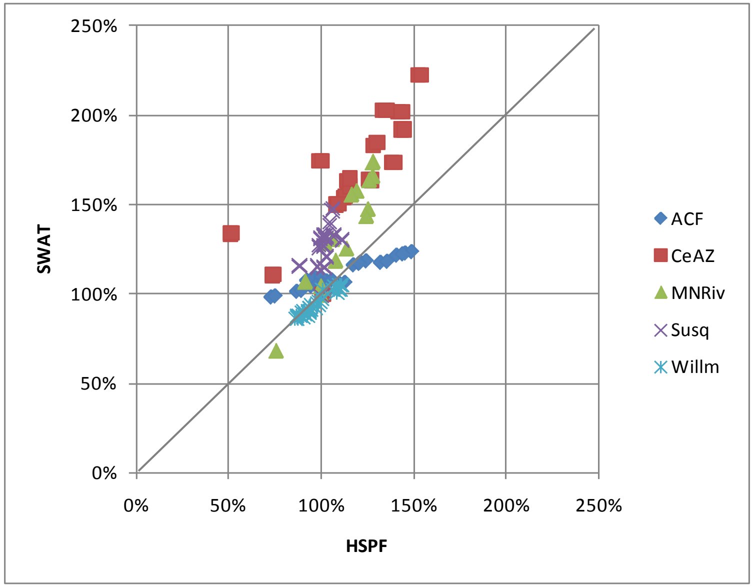
Also provides overview of:

1. Overall hydrologic and WQ response to climate change
2. Geographic differences in response
3. Different sensitivities of different flow and WQ endpoints

Comparison of HSPF and SWAT-simulated changes relative to existing conditions (5 pilot basins; all 28 scenarios)

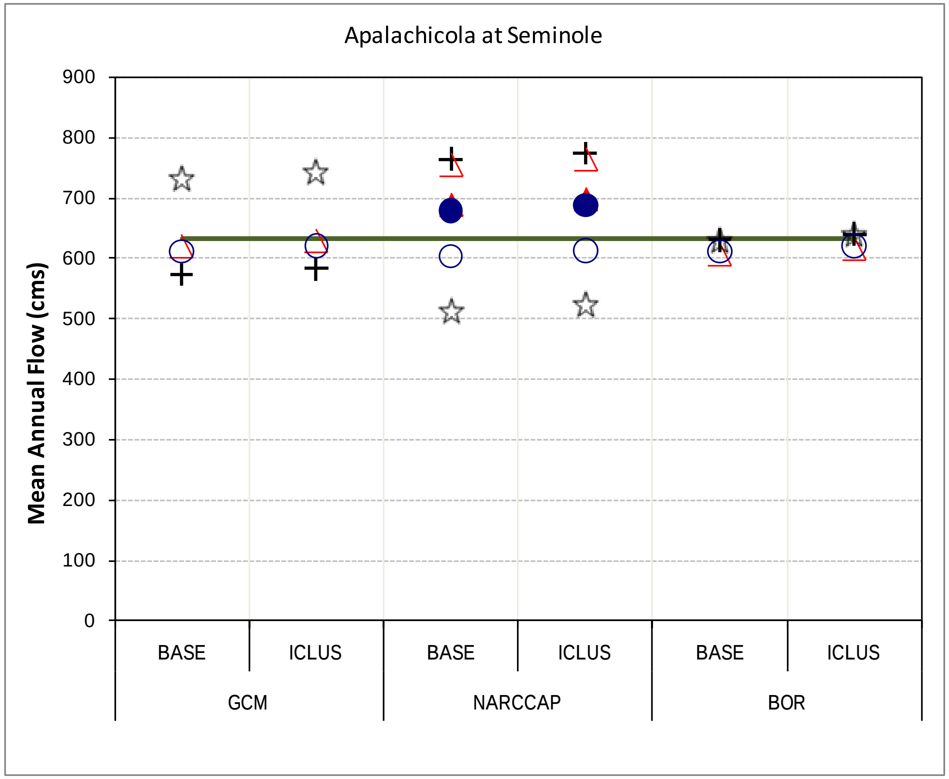


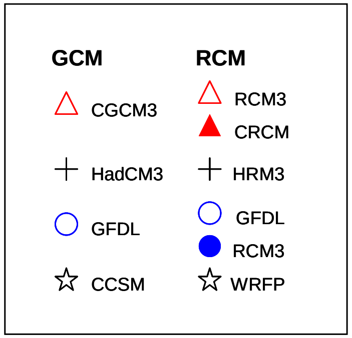
Total Streamflow



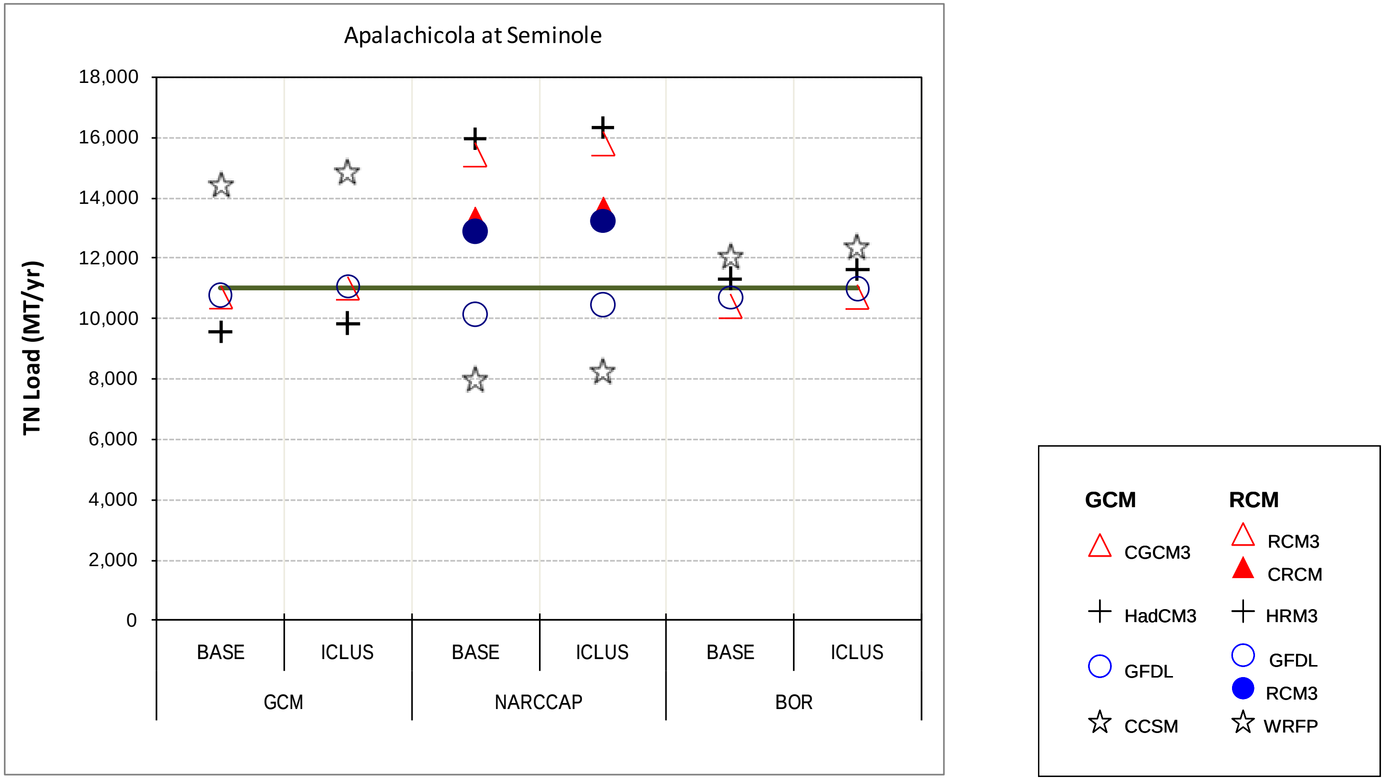
Total Nitrogen

Mean Annual Flow (cms)
Apalachicola River at Seminole (HSPF)





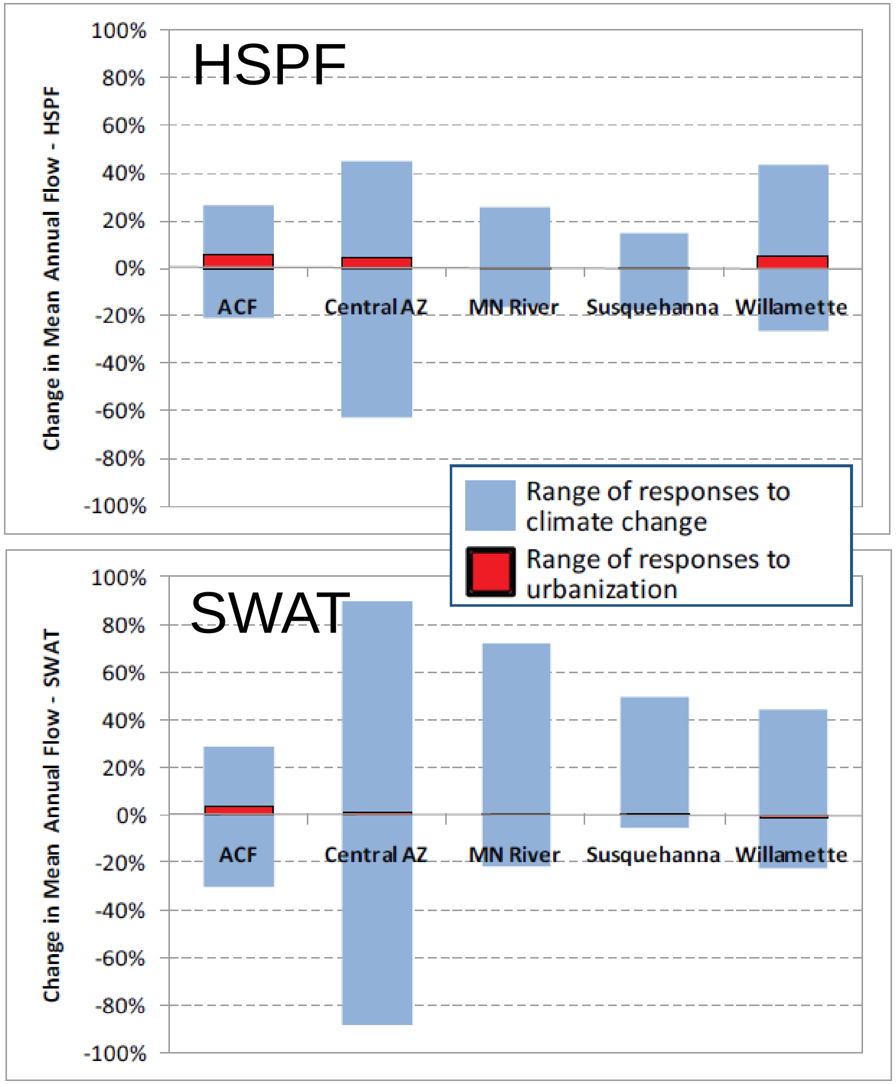
TN Load (MT/yr)
Apalachicola River at Seminole (HSPF)



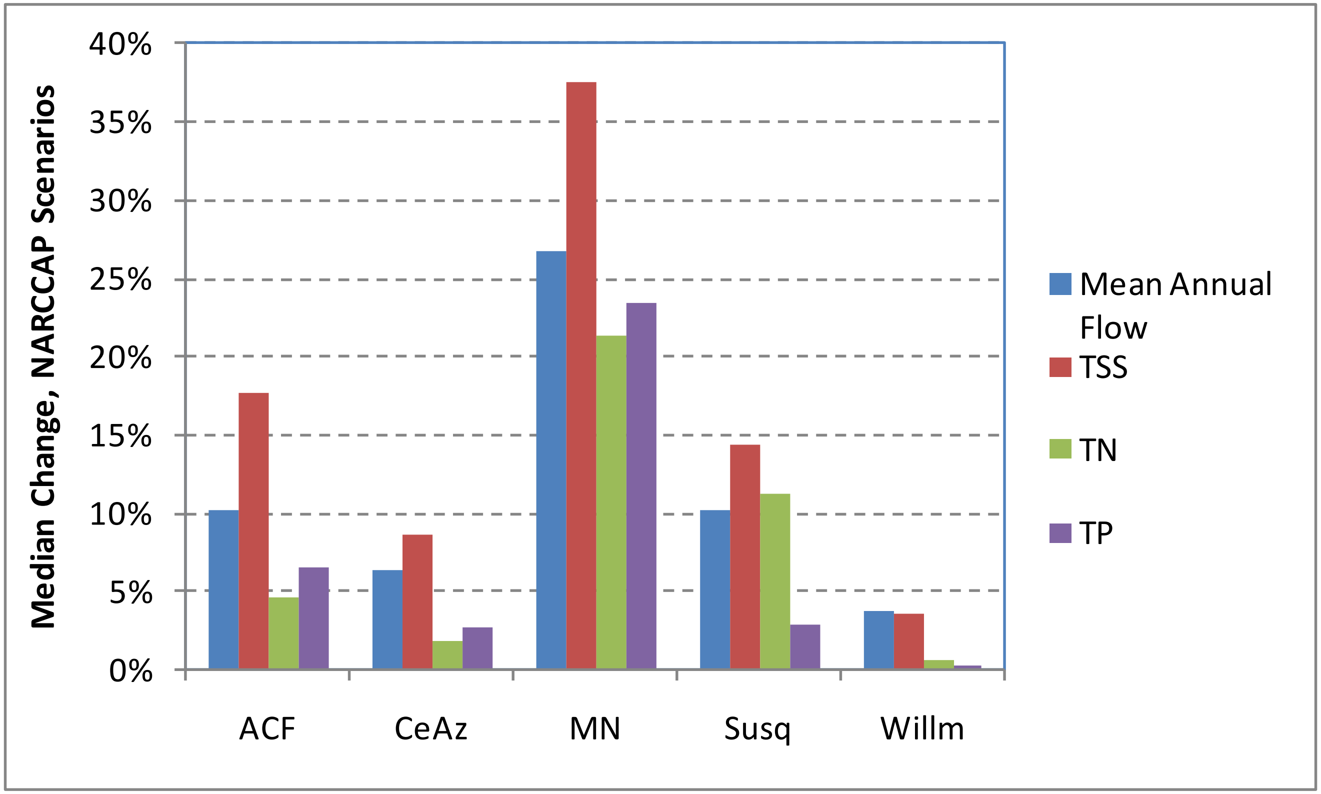
Range of simulated changes in mean annual streamflow in response to projected 2041-2070 climate change (blue) and projected 2050 changes in urban development (red)

Projected % changes in urban land (EPA ICLUS)

ACF	= 3.6
CentralAZ	= 0.5
Minn. River	= 0.7
Susque. R.	= 0.7
Willamette	= 1.4



SWAT Simulated Response to Increased Atmospheric CO_2 Concentration



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20 Watersheds Project – A Few Insights

Sensitivity to climate change highly variable among endpoints

Different downscaling approaches can increase the variability of response

Climate change, urbanization, and increased atmospheric CO_2 can have synergistic effects on streamflow and pollutant loading

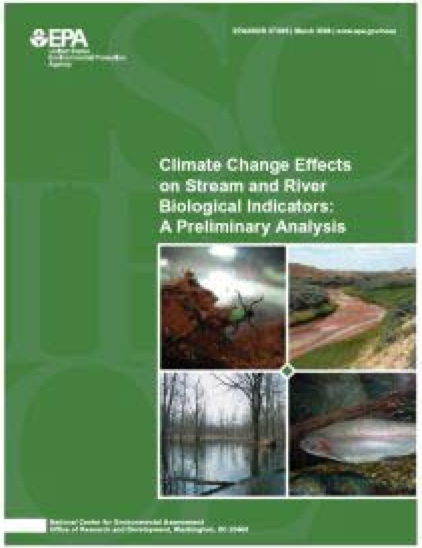
At the ~HUC8 scale considered here, projected mid-21st century climate change larger influence than urbanization; not true as scale decreases, needs further study

Climate Change and Biological Indicators

- Climate change is an "additional" stressor that affects both reference & non-reference sites
- Consequences for biocriteria program management goals
  - Difficult to establish goal if baseline is changing
  - Or goals may be impossible to meet

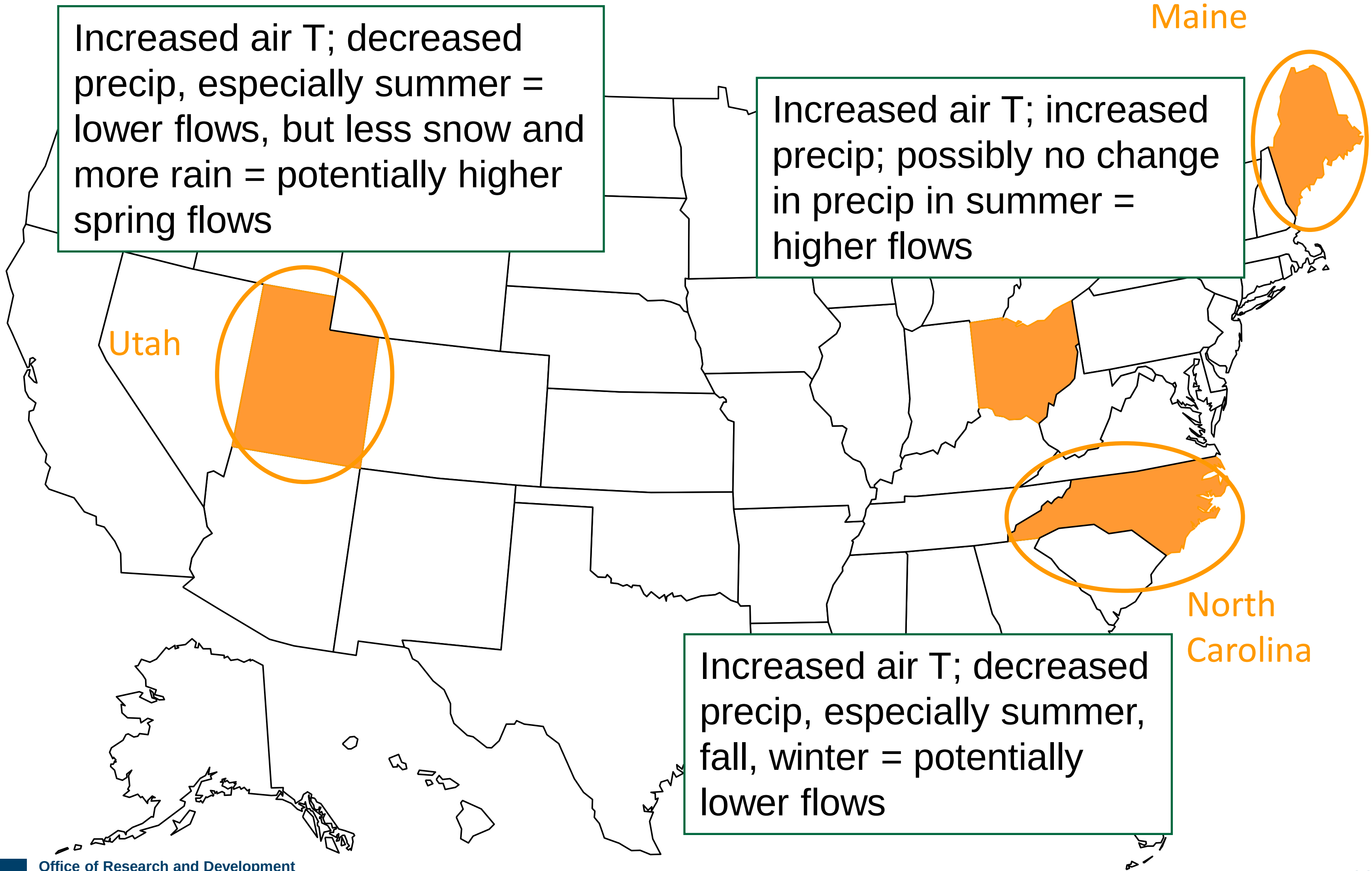
Analysis of Effects on Biological Assessments

- Categorized biological indicators according to sensitivity to climate change
- Conducted case studies on effects on reference and non-reference sites and monitoring strategies
- Held workshops for biocriteria managers (Spring ’07 & ’08)
- Final report available on EPA/NCEA website under Global Change*



* http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190304

Pilot Studies on Climate Effects on Biological Indicators



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How Can Science Support Decision-Making?

Two Strategic Framings of CC Impacts Assessment

Paradigm 1: "Predict Then Act"

- Figure out what you think is the most likely future
- Design the best policy you can for that future
- Conceptual framework: "Maximize expected utility"
- **Question: "What will happen?"**

Paradigm 2: "Assess System Vulnerabilities/Policy Risks"

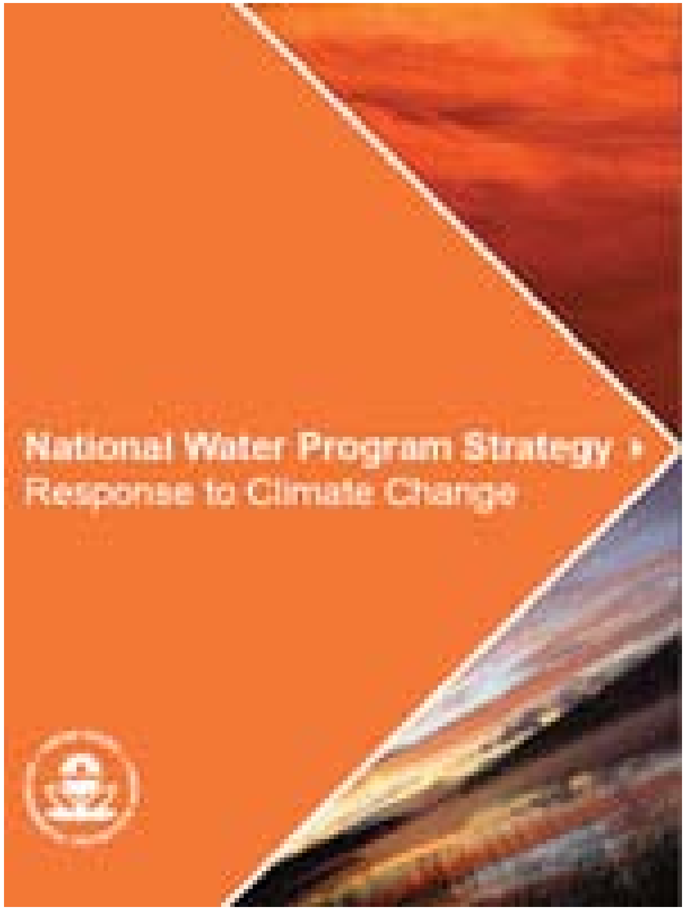
- Identify greatest vulnerabilities across full range of plausible futures
- Identify suite of policies that are robust across this range
- Conceptual framework: "Minimize regret"
- **Question: "How does the system work?"**

Robust Decision Making (RDM)

Scoping Study: Evaluate the Potential for RDM Methods to Support EPA Water Program Climate Adaptation Actions

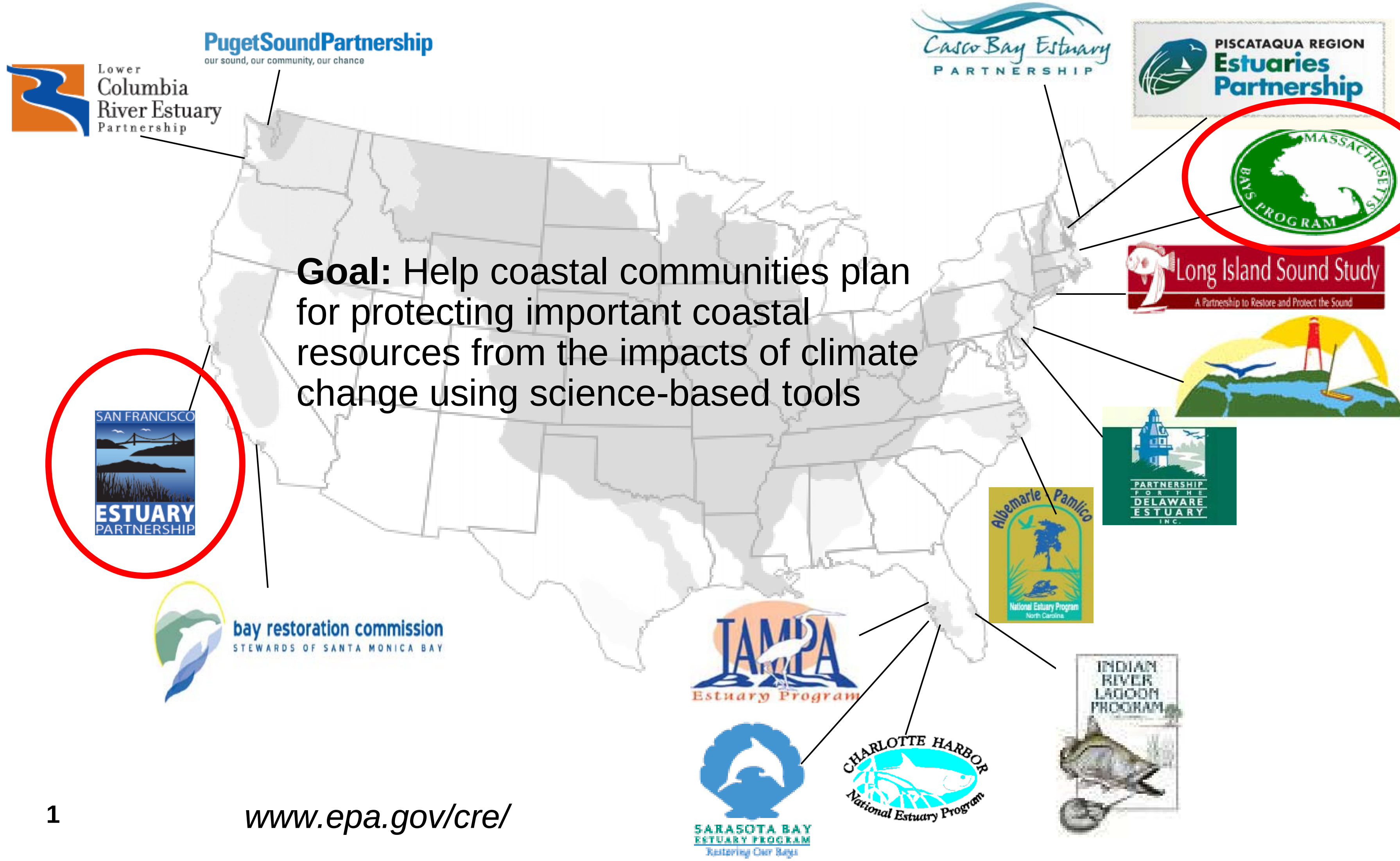
The primary criteria for appropriateness of RDM are threefold:

1. The existence of deep uncertainty about the potential impacts of climate change on a management goal
2. The existence of a sufficiently rich space of alternative decision options (EPA National Water Program) in addressing this issue
3. The existence of computer simulation models that can satisfactorily compare the performance of alternative decision options of interest to the decision makers (as not all scenario exercises have appropriate models readily available)



CLIMATE READY ESTUARIES EPA

Climate Ready Estuaries Program



Goal: Help coastal communities plan for protecting important coastal resources from the impacts of climate change using science-based tools

www.epa.gov/cre/

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Vulnerability Assessment Approach

- Review ecological goals from Comprehensive Conservation and Management Plan
- Create conceptual models for key ecosystem processes
- Assess sensitivities of processes across a range of climate change scenarios
- Assess vulnerabilities of management goals to inform adaptation planning

Example Ecosystem Processes For Assessment Focus

Salt Marsh
Sediment Retention

The balance between the processes of removal and deposition of sediment

Community Interactions:
Shorebirds

Access of Western sandpiper and Marbled godwit to mudflat prey

‘Top Management Pathways’ For Sediment Retention

Example Results

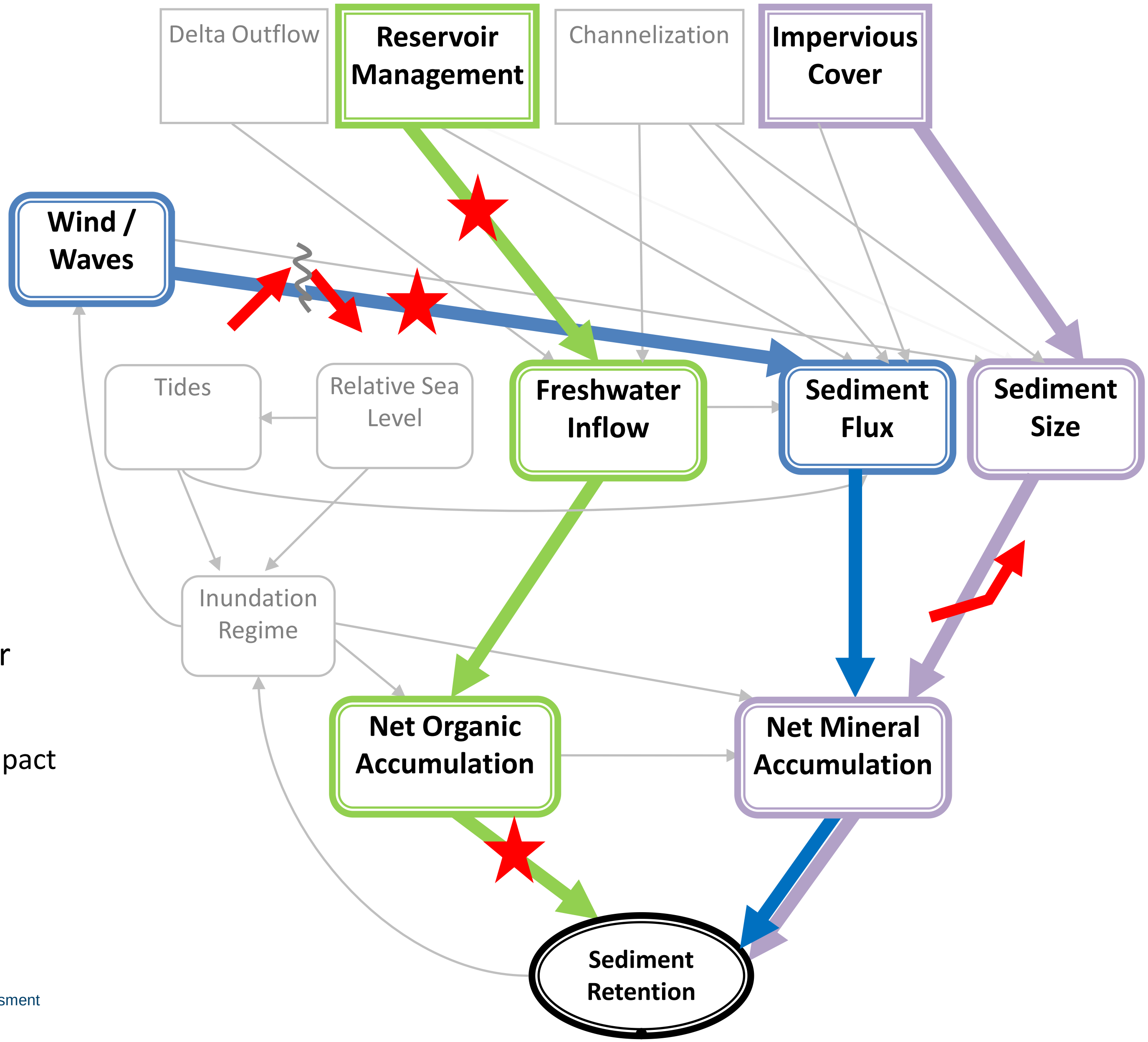

Figure Key:

Changes Expected Under Future Climate

Increasing relative impact

Increasing sensitivity

Threshold

Public Input to the National Climate Assessment

- The public is invited to participate in the NCA
    - For the 2013 Report:
        - Expressions of interest (EOI) are due by October 1, 2011
        - Final inputs are due by March 1, 2012
    - For the ongoing process, EOI and technical inputs welcome anytime

- Technical inputs to the NCA including (but not limited to)
    - literature reviews
    - discussion papers
    - case studies
    - modeling results, interpretation of data
    - topical reports.

- For more information see: http://www.globalchange.gov/

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Future Directions

How do we develop meaningful bounds on uncertainty in future scenarios?

How can large-scale contextualization be most effectively used for place-based research?

How transferable/generalizable are place-based results?

How would a synthesis to draw national-level conclusions re. climate change impacts on water quality and ecosystems be done?

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EPA ORD NCEA Global Program

- **Amanda Babson**
- **Alicia Barnash (ORISE)**
- **Britta Bierwagen**
- **Chris Clark**
- **Janet Gamble**
- **Anne Grambsch**
- **Susan Julius**
- **Philip Morefield**
- **Meredith Warren (ORISE)**
- **Jordan West**
- **Chris Weaver**

Thanks!

johnson.thomas@epa.gov

Phone: 703-347-8618

http://www.epa.gov/ncea/global/