Assessing Hydrologic and Water Quality Sensitivity to Global Change

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The Project

- USEPA ORD Global Change Research Program is charged with evaluating vulnerabilities of natural and human systems to global change.
- Global change includes both climate change and land use change.
- Responses of watershed hydrology and water quality are particularly uncertain and in need of further study.
- Multi-year contract to develop the assessment:
  - Brings together scientists from GCRP, Tetra Tech, Aqua Terra, and Texas A&M.
  - Just moving to results phase.

Obligatory disclaimer: *The views expressed in this presentation are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.*
Climate is changing...

- Warming of the climate system is unequivocal (regardless of the cause) as is evident from:
  - Increases in global average air and ocean temperatures (~0.74 °C/century)
  - Widespread melting of snow and ice
  - Rising global average sea level (~1.8 mm/yr since 1861)

- Regionally variable changes have occurred in the amount, intensity, and form of precipitation during the last century

- Trends are expected to continue or accelerate (IPC, 2007)
Watersheds are vulnerable

- Managing climate related risk will require an understanding of potential impacts and development of adaptive strategies
  - impacts/risk will vary regionally

- Change highly uncertain, we don’t have accurate forecasts (at necessary spatial scale)
What can we do?

► High levels of uncertainty demand an ensemble approach – for both climate forecasts and watershed response

► Even though they can’t give us predictions, simulation models can be used to develop change scenarios over a range of possible outcomes

► These scenarios can be used to systematically explore the implications of different futures

► This process allows us to identify where the greatest vulnerabilities lies, and which response options are robust, given a particular decision context
EPA GCRP 20-Watershed Modeling Study

Watershed modeling in 20 US watersheds (~20,000 mi²)
Focus on streamflow, sediment, and nutrient loads

Purpose:

• understand sensitivity/vulnerability to climate and land-use change
• Develop hydrologic and water quality change scenarios for 2040-2070

Pilot watersheds (5):

• 2 models, HSPF and SWAT (ensemble approach)
• 14 climate change scenarios (from NCAR NARCCAP)
• 2 land-use change scenarios

Additional watersheds (15):

• 1 model, 4 climate change scenarios, 2 land-use scenarios
20 Watersheds – Study Sites

Legend
- Municipalities (pop ≥ 50,000)

GCRP Model Areas

Map produced 11-04-2009 - A. Parks/S. Job
Southeastern Study Sites

- Apalachicola-Chattahoochee-Flint (ACF) – Pilot Site
- Neuse-Tar-Pamlico – Additional Site
- Florida – Georgia Coastal Basins (Tallahassee to Tampa) - Additional Site
Climate change scenarios

► Core of regionally downscaled climate change scenarios from NCAR North American Regional Climate Change Assessment Program (NARCCAP) [A2 emissions scenario]

► Compare future (2040-2070) to present (1970-2000)

► Compare (expensive) dynamic downscaling [~50 km] to raw GCM [~1°] and statistical downscaling

► Data interpolated to NCDC station locations used in watershed model calibration
  ▪ Delta change method to create hydro model inputs (BASINS CAT)
  ▪ PET using Penman-Monteith to account for concurrent changes in wind, insolation, humidity, etc.
NARCCAP Simulation Strategy

IPCC A2 Emissions Scenario

Global Climate Models (GCMs)

- GFDL U.S. (NOAA)
- CGCM3 Canada
- HADCM3 UK
- CCSM U.S. (NCAR)

1970-2000 current
Provide boundary conditions
2040-2070 future

High-Resolution Regional Climate Models (RCMs) Over North America

- MM5 (Département de l'Environnement, PNNL)
- RegCM3 (UC Santa Cruz, ICTP)
- CRCM (Ouranos, Québec)
- HADRM3 (Hadley Centre, UK)
- RSM (NOAA/IFSN)
- WRF (NCAR/PNNL)
Land-use change scenarios

- National scale projections of housing density (1 ha resolution) and impervious cover (1 km resolution) from NCEA’s Integrated Climate and Landuse Change Scenarios (ICLUS) project
- Future 2050 (same as climate)
- Scenarios consistent with IPCC SRES A2 storyline (same as climate)
- Discharges, withdrawals, reservoir operating rules held constant
Some Preliminary Results for the ACF

- 19,600 square miles
- Contains Atlanta and its water supply (Lake Lanier)
- Subject to long-running legal disputes over fair management of the system
- Good flow gaging and precipitation records
Model Development and Calibration

- Calibration/Validation is essential for adequate watershed model performance
  - Models based only on geographic information without calibration tend to perform poorly
  - However, calibration does raise issues for extrapolation
- Both HSPF and SWAT models developed for the basin
  - Initial calibration to the Upper Flint; extension to whole
  - Both models perform adequately
  - Future scenarios based on modification of 1973 – 2002 weather
Model Performance – Flow, Flint River
Model Performance – Water Quality

TSS

Total P

Regression Loads
Simulated Loads
Change Scenarios

- Contains wide ecosystem range – Blue Ridge to Gulf of Mexico
- Climate scenarios – change statistics applied to 38 driving met stations
- Also anticipate significant land use change (e.g., Atlanta metro area)
Climate for 2040-2070: Temperature

- RCM – downscaled models agree on consistent increase in temperature
- This will also cause an increase in PET
Climate for 2040-2070: Rainfall

- Rainfall changes much less clear
- May increase or decrease depending on GCM used – depends on forecast position of jet stream and fronts
- Seasonal shifts possible
- Intensity changes expected
GCMs without downscaling and BOR
statistical downscaling can provide quite
different results for the ACF...
Resulting flow volumes (a function of rainfall amount, intensity, and PET) also show a spread of possible futures...

Median change in total flow: +7%; range -20 to +23%
...as do future pollutant loads
Land use change does not have a significant effect at the whole-basin scale, but will have local impacts.
Water supply to Lake Lanier: Little change anticipated in average flow for 2040-2070
...but drought risk may increase, particularly under the WRFP downscaling of the CCSM model.
For perspective: Contrast results from Minnesota. There, the climate projections agree on increases in winter-spring flows, but disagree on growing season conditions.

Median increase in annual flow: 14%
Implications

*Models tell us to expect change in hydrologic systems*

► Stationarity is dead?
► Temperature, sea level will rise (with high probability)
► Unfortunately, it is not clear what change is expected in overall hydrologic response in the Southeast
► Do expect increased variance in response – more extremes (drought, floods) are likely
► Uncertainty in predictions calls for a larger margin of safety in infrastructure design and water quality protection
Caveats

► Direct prediction from GCMs may not be informative at the watershed scale
  ▪ Application of RCMs can yield very different results
  ▪ Statistical downscaling does not resolve
► But, RCMs available only for the SRES A2 storyline – other possible futures exist
► At this point, cannot fully incorporate additional feedback loops:
  ▪ Forest mortality, shift in ecoregions and plant feedback
  ▪ Human adaptation (e.g., shift in crop types)
  ▪ Changes in future discharges, withdrawals, water use, and water reuse associated with human adaptation
Closing comments

► Climate change is a “lens” through which we should reexamine traditional water and ecosystem management.

► Given deep uncertainty about global change, we can use models to seek solutions that are robust across a range of high risk futures.

► Important to examine a range of geographies and climate conditions as the nature of change and associated impacts are expected to vary.

► EPA GCRP’s modeling in 20 US watersheds will help understand sensitivity/vulnerability to both climate and land-use change at both the national and local scale, informing the policy debate about appropriate adaptation strategies.