Linking Atmospheric Mercury Deposition to Human and Wildlife Exposure (Source to Receptor) by Coupling VELMA and WASP to BASS to Simulate Fish Tissue Concentrations

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Presentation Outline

- Research Background and Motivation
- Research Questions and Research Approach
- Modeling Framework
- Model Results
- Future Research
Research Background

- In the USA as of 2010
  - Hg fish advisories
    - 50 states
    - 1 US territory
    - 3 tribes
  - 81% of all fish advisories in US surface waters are at least partially due to mercury
  - 2,100,000 km of rivers
  - 3,710 Hg Advisories

http://water.epa.gov/scitech/swguidance/fishshellfish/fishadvisories/technical_factsheet_2010.cfm
Research Motivation

- US surface waters are impacted by Hg
- > 2,000,000 km of rivers have Hg fish consumption advisories
- Atmospheric deposition is the primary source of Hg to many ecosystems
- **Streams** and **rivers** are intimately linked with their watersheds
- Need to understand factors governing Hg transport, transformation, and bioaccumulation
Research Questions

- What processes and factors govern Hg exposure concentrations in streams and rivers?

- How do we model the link of atmospheric Hg deposition to fish tissue Hg to increase our understanding and ability to predict wildlife/human exposure risk?

- How can we use focused, site-based (field) research studies to understand Hg exposure at larger scales (regional, national)?
Research Approach

- Use mechanistic, differential mass balance models to simulate the fate and transport of mercury
  - Land, subsurface, surface water, sediments, fish

- Use linked multi-media framework to simulate Hg exposure concentrations up to larger scale systems

- Use focused reach study to calibrate watershed modeling of Hg

- Use individual models to evaluate governing processes and use linked models as a systems level approach
Research Approach: Mechanistic Models

Why use Mechanistic Models?

• Mechanistic Model: Understanding the behavior of a system’s components and how they interact

• For Understanding
  • How well model represents observed data
  • How well do we understand governing processes
  • Both model success and failure provide insight

• For Predictions
  • Future exposure concentrations
  • Scenario evaluation
    • Compare management strategies
  • Model scaling
  • Modeling different locations and sites
Multi-Media Modeling Framework

Atmospheric Deposition
CMAQ / MDN

Watershed
VELMA

Surface Water
WASP

Bioaccumulation
BASS
Research Approach: Mechanistic Models

VELMA: Visualizing Ecosystems for Land Management Assessment

- Simulates
  - Hydrology (Runoff, groundwater for 4 soil layers)
  - Carbon: Dissolved Organic and Soil Organic
  - Nitrogen: Ammonium, Nitrate, Dissolved Organic
  - Mercury: MeHg, Hg$^{2+}$
  - Processes: methylation, demethylation, reduction/evasion

WATERSHED and GROUND WATER
Research Approach: Mechanistic Models

**SURFACE WATER** and **SEDIMENTS**

- **WASP: Water quality Analysis Simulation Program**
  - Simulates
    - Media: Water Column and Sediments
    - Stream Flow Hydrology
    - Fines, Sands, Particulate Organic Matter
    - Mercury: MeHg, Hg(II), Hg(0)
    - Processes: methylation, demethylation, oxidation, reduction, sorption, settling, resuspension
Research Approach: Mechanistic Models

FISH COMMUNITY and BIOACCUMULATION

- **BASS: Bioaccumulation and Aquatic Simulations Simulator**
  - Simulates
    - Population dynamics of age-structured fish communities
    - Hg in fish tissue for each age cohort of fish species present
Study Site: McTier Creek Watershed, SC, US

- Sand Hills region of Upper Coastal Plain, SC
- 79 km² drainage area
- Mixed land cover: 49% forest, 21% grassland and herbaceous, 16% agriculture, 8% wetland, 5% developed, 1% open water
- Shallow groundwater system
  - Low – normal flow: toward stream channel
  - High flow: same with increased area of groundwater-surface water exchange
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Focused Reach Study
Focused Reach Study:

Watershed spatially explicit
3 dimensions
4 soil layers
30m x 30 m area

Processes in Each Soil Cell
Methylation / Demethylation
rates = function of T and soil moisture

Mercury flows with water
Competing processes of
Dissolved Organic Carbon complexation
sorption to soil matrix

Water can move in any direction
Focused Reach Study
McTier Creek Watershed Modeling: VELMA

New Holland, 79.4 km²
Linking VELMA Output to BASS
McTier Creek Fish Community

- yellowfin shiner
- blackbanded darter
- bluehead chub
- margined madtom
- bluegill
- speckled madtom
- dusky shiner
- snail bullhead
- tessellated darter
- redbreast sunfish
- Savannah darter
- turquoise darter
- warmouth
- dollar sunfish
- swamp darter
- tessellated darter
- coastal shiner
- redfin pickerel
- creek chubsucker
- creek chub
- pirate perch
- largemouth bass
Linking VELMA Output to BASS

Yellowfin Shiner

Tesselated Darter

Large Mouth Bass

Blackbanded Darter
Future Research Questions

- Linking VELMA and LOADEST MeHg w/BASS predicted relatively well
- Fish Tissue Hg
  - Yellowfin Shiner: Overpredicted
  - Tesselated Darter: Well predicted
  - Large Mouth Bass: $n = 3$, falls within range
  - Blackbanded Darter:
    - Wide range of observed
    - Simulations on low end of observed
Future Research Questions

- The phase of VELMA simulated MeHg concentrations are out of phase with the observed and LOADEST
- VELMA having fish Hg out of phase and VELMA slightly higher than LOADEST
- Are flow paths not adequately represented in VELMA?
- Importance of wetlands?
  - How can we represent wetlands in VELMA?
  - Should a water quality model be used?
- Link VELMA to WASP
  - Does this improve predictions of THg and MeHg?
  - Is it worth additional modeling cost/effort?
- Should wetlands be simulated in WASP rather than VELMA?
- Are wetlands a watershed component or a surface water component?
Can we then use McTier Creek to simulate THg, MeHg, and fish tissue Hg on a regional scale?

Continuing linkage of VELMA and BASS?
Do we need to incorporate WASP to link HUC12s together and capture instream processes?
What is the best modeling framework design to simulate regional basins?

Mechanistic model comparison/evaluation.

Is VELMA+WASP+BASS >> VELMA + BASS?