Developing and Applying Next-Generation Watershed Models Using OMS

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Object Modeling System (OMS)

Initial Goal:
A computer framework and a library of modules that facilitates the assembly of a modular modeling package, specific to a region, problem, data constraints, or scale of application.

Now: being extended as an application and delivery platform.

Developed in collaboration with:
- NRCS, USGS, Colorado State University,
- Friedrich-Schiller University, Jena, Germany
Advantages of OMS

- Supports building of new models and decision tools from a library of reusable components.
- Uses the best or most appropriate science for each component.
- Improves code quality. Easier to follow by other modelers and pass on to the next generation.
- Makes long-term maintenance and update of models easier and less costly.
- Eliminates duplication of work by modelers. The library of modules serves as a reference and a coordination mechanism for future research and model improvements.
Advantages of OMS

- Streamlines model building and applications. Reduces IT integration challenges for researchers.

- Enhances deployment of new tools by action agencies (NRCS) with established databases.
OMS Principal Architecture
Component-Based Modeling Example

System Components
Data IO
Time
Space
Control
Statistics

Auxiliary Components
Calibration
Parameter Estimation
Sensitivity Analysis
Uncertainty Analysis
Visualization
Forecasting

Science Components
Erosion
Plant Growth
Groundwater
Water Quality
ET
...
Cloud Services Innovation Platform (CSIP) for Remote Applications of Models

- Implement Modeling Infrastructure that is:
  - Cost effective (→ Cloud)
  - Highly interoperable
  - Component-based (→ OMS3)
  - Computational scalable
  - Scalable for data (→ NoSQL)

- Prototype Selected Models Via CSIP
  - RUSLE2, AgES-W, …
The OMS Greatly Facilitates the Development and Use of Models and Conservation Tools by Action Agencies
A Next-Generation, Process-Based AgES Model for Delivering Precision Conservation at Landscape and Watershed Scales

- 130+ components selected from J2000, SWAT, WEPP, RZWQM, and other models
- RUSLE/MUSLE/WEPP erosion
- Updated water & N Dynamics for soil/groundwater/stream
- Land use/tillage management
- Tile drainage
- Crop production, economics!
Expansion of model functionality using SWAT, RZWQM2, AnnAGNPS, PRMS, and WEPP modules

AgES Watershed Model

- Plant Growth Module
  - Biomass
  - Rooting Depth
  - LAI

- Soil Temperature Module

- Soil Nitrogen Module
  - Nitrification
  - Denitrification
  - Volatilization
  - Plant Uptake

- Water Balance (Unsat.)
  - Infiltration
    - DPS
  - MPS
  - LPS

- Water Balance (Sat.)
  - Upper Zone
  - Lower Zone

- Interception

- Driving data: P, T, ...
- Additional drivers: Radiation ...

- MUSLE Erosion
- Surface Runoff
  - Surface RO
  - Interflow 1
  - Interflow 2
  - Baseflow

- Snow
Hydrologic Response Units in AgES

- Delineation Based on GIS Overlay
  - Topography
  - Land Cover
  - Soil Types
  - Hydrogeology

- This process-oriented classification of catchments does not lose any important information

- Combined with a topological routing scheme, vertical and lateral processes can be modeled fully distributed by HRUs
AgES Compared to SWAT Model

• The semi-distributed SWAT concept averages HRU information within a sub-watershed

• Important processes, e.g., lateral water/nutrient transport, and specific management and conservation effects cannot be simulated for individual HRUs

The fully distributed AgES Watershed Model contains updated state-of-the-science code and allows distributed simulation of important processes by HRUs.
Cedar Creek Watershed (CCW), Indiana
- Basin area: 707 km²
- Avg. precip: 900 mm (35”)
- 76% of watershed agricultural, 21% forest, 3% urban

GIS Inputs:
- 30 m DEM (USGS)
- STATSGO and SSURGO soils (NRCS)
- Land use (NASS 2001)
Current AgES-W focus is on evaluating N and sediment (MUSLE erosion) components.

CCW monthly observed and AgES Watershed Model simulated stream flow (1997-2005) using a manually calibrated parameter set.
AgES Auxiliary Tools

- AgES GUI (NASA WorldWind™)
- ArcGIS 10 Watershed Delineation Tool
- Natural Resource Model Visualizer (NRMV) Tool

Space-Time-Scenario 2D Output Visualization
Real-Time Dynamic Color Ramping
3D Visualization of Simulation Land Units
Output Querying Across Land Units
AgES Future Research (2011-2015)

Objective 1: Further develop and apply AgES-W to evaluate the long-term effects of management on water quantity/quality and production in Colorado and the Midwest.

Objective 2: Evaluate effects of spatially targeted conservation effects on water quantity/quality.

Objective 3: Evaluate the effects of projected climate change on water use, water quality, and production; develop potential adaptations.
GPFARM-Range Functions

- **Forage Crop Growth**
  Simulating biomass production of cool season grasses, warm season grasses, legumes, shrub, and forbs with animal grazing.

- **Animal Production**
  Simulating animal weight gain/loss.

- **Hydrology**
  Crop ET, soil water, runoff, and seepage.

- **Carbon-Nitrogen Cycling**

- **Climate Change**
  CO₂ impacts on forage growth, response of crop and CN to temperature and rainfall.
GPFARM-Range to Manage Herd size and Grazing Intensity on a Landscape

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- Can simulate 10 paddocks and rotational grazing
RZWQM calculated annual nitrate reduction (kg N/ha) in tile water by “Controlled Drainage” (left) and “cover crop” (right) in the U.S. Midwest- Regional scale.
SUMMARY

• OMS-based AgES and GPFARM-Range represent next generation models that can be customized to deliver system-based, site-specific precision conservation.

• Identify/deliver spatially targeted conservation.

• Allow fast remote applications via smart phones and ‘CLOUD COMPUTING.’

• Provide uncertainties and economic risk associated with conservation effects.

• Allow quick updates with improved model components and new management options, contributed by experts world-wide.

• Use common quality data and analysis tools.
Thanks Very Much for Your Attention!

We Seek Your Thoughts!