Simulation of hydrologic and water quality processes in watershed systems using linked SWAT-MODFLOW-RT3D model

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Motivation  Improve groundwater flow and solute transport processes in SWAT

Method  Link SWAT with physically-based, spatially-distributed groundwater models
Outline

• Model Overview
• Model Code
• Modeling Linkage
• Applications: Klamath Basin, OR

Little River Watershed, GA
Model Description

Linking 3 Models:

SWAT

MODFLOW
- Groundwater model
- 3D finite difference

RT3D
- Reactive transport
- 3D finite difference
Model Description

Linking 3 Models: SWAT
MODFLOW
RT3D

SWAT-MODFLOW-RT3D

Model Overview

Model Code

Model Linkage

Klamath Basin, OR

Little River, GA
Linking 3 Models:

- **SWAT**
  - Soil percolation
  - Potential ET not satisfied
  - River Stage
  - Pumping required
  - N, P in percolating water
  - N, P in stream water

- **MODFLOW**
  - Water Table height
  - GW/SW Interaction
  - Groundwater flows, sources/sinks

- **RT3D**
  - N, P concentrations in vadose zone
  - Mass of N, P to/from Surface Water
  - N, P concentrations in saturated zone

**Daily Interactions**

**Klamath Basin, OR**

**Little River, GA**

**Model Overview**

**Model Code**

**Model Linkage**
**Model Code**

1: subbasin (hru calculations)

19: MODFLOW / RT3D

- Map SWAT variables $\rightarrow$ MODFLOW Grid
  - Recharge (soil percolation)
  - NO$_3$ concentration in percolation water
  - Stream stage

Run MODFLOW

Run RT3D

- Map Grid $\rightarrow$ SWAT
  - GW Discharge $\rightarrow$ Subbasin streams
  - NO$_3$ loading $\rightarrow$ Subbasin streams

**Model Overview**

*Klamath Basin, OR*

*Little River, GA*
1. HRU \( \rightarrow \) DHRUs
2. DHRUs \( \rightarrow \) Grid Cells
3. River Cells \( \rightarrow \) Subbasin

JAVA code

map_dhru2grid.txt
map_dhru2hru.txt
map_grid2dhru.txt
map_river2grid.txt
Model Linkage

User Interface

MODFLOW Input Files

- LittleRiver.bas
- LittleRiver.dis
- LittleRiver.lmt
- LittleRiver.nam
- LittleRiver.nwt
- LittleRiver.oc
- LittleRiver.rch
- LittleRiver.riv
- LittleRiver.upw

- MODFLOW-NWT.exe

map_dhru2grid.txt
map_dhru2hru.txt
map_grid2dhru.txt
map_river2grid.txt

SWAT input files

SWAT-MODFLOW Simulation
Klamath Basin, Oregon

MODFLOW Model
- USGS (2012)
- 1970-2004
- 100,000 grid cells

SWAT Model
- Records et al. (2014)
  Hydrol. Earth Syst. Sci. 18: 4509–4527

Upper Klamath

Klamath River Basin

Sprague Watershed

Klamath Basin, OR

Little River, GA
Simulation Results

Annual Recharge

Water Table Elevation

Annual average recharge (mm)
Value
High : 496
Low : 0

SWAT-MODFLOW Water Table Elevation
Value
2025 m
1268 m

Sprague River

0 5 10 20 Kilometers

0 5 10 20 Kilometers
Klamath Basin, Oregon

Simulation Results

Groundwater Discharge to Streams

Average Groundwater Discharge

12,000 m³/day

0

-12,000 m³/day

Sprague River Basin

North Fork Subbasin
Simulation Results

Nitrate Concentration in Groundwater

Klamath Basin, Oregon

Model Overview
Model Code
Model Linkage
Klamath Basin, OR
Little River, GA
Klamath Basin, Oregon

Simulation Results

Groundwater Nitrate Loading to Streams

Model Overview
Model Code
Model Linkage
Klamath Basin, OR
Little River, GA
Little River Watershed, GA

Collaboration with Grassland, Soil and Water Research Laboratory (Katrin Bieger, Hendrik Rathjens)

http://nsidc.org/data/docs/daac/nsidc0329_smex03_little_river_micronet_ga.html
Objective: Couple SWAT with MODFLOW

1. Steady state MODFLOW model
2. SWAT-MODFLOW transient model
3. Calibration and Testing
Little River Watershed, GA

Collaboration with Grassland, Soil and Water Research Laboratory (Katrin Bieger)

MODFLOW Grid

Aquifer Thickness
2-10 m

Model Code

Model Linkage

Klamath Basin, OR

Little River, GA
Simulation Results

Groundwater Discharge to Streams

8,000 m³/day
Discharge

-8,000 m³/day
Seepage

Little River Watershed, GA

SWAT-MODFLOW-RT3D

Model Overview
Model Code
Model Linkage
Klamath Basin, OR

Little River, GA
Summary

- **SWAT-MODFLOW-RT3D model**
- **Applied to two watersheds**
- **GIS/Java Pre-processing tools for linkage**
  - HRU → Disaggregated HRUs
  - DHRUs → Grid Cells
  - Grid Cells → SWAT subbasins
- **Developing: User Interface** Hendrik Rathjens
  - Create simple MODFLOW model
  - Create linkage files
- **Public Domain (SWAT code)**

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Thank you
Model Linkage

Intersections

1. HRU → DHRUs
2. DHRUs → Grid Cells
3. River Cells → Subbasin

Model Linkage

1. DHRU_grid.csv
2. FullDHRU.csv
3. rivergrid.csv

JAVA code
- map_dhru2grid.txt
- map_dhru2hru.txt
- map_grid2dhru.txt
- map_river2grid.txt

Klamath

map_dhru2grid.txt