AN INTEGRATED HYDROLOGIC MODELING FRAMEWORK FOR COUPLING SWAT WITH MODFLOW

J.A. Guzman[1], D.N. Moriasi[1], P.H. Gowda[2], J.L. Steiner[1], J.G. Arnold[3], R. Srinivasan[4], and P.J. Starks[1]

[1] Grazinglands Research Laboratory, USDA-ARS, El Reno, OK
[2] Conservation and Production Research Laboratory, USDA-ARS, Bushland, TX
[3] Grassland Soil and Water Research Laboratory, USDA-ARS, Temple, TX
[4] Texas A&M, Spatial Science Laboratory, College Station, TX

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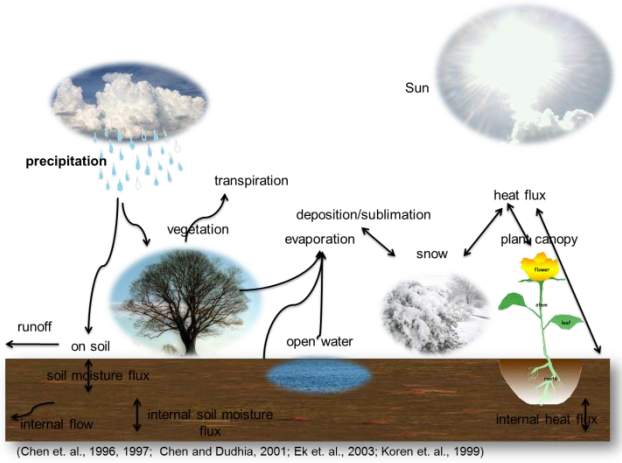
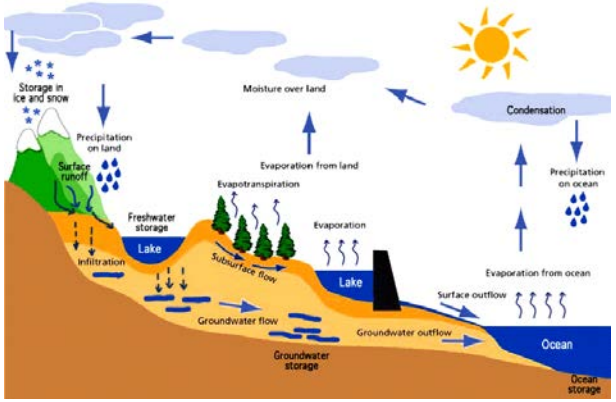
WHY DO WE COUPLE SWAT and MODFLOW, and INTEGRATE SWAT and EB_ET MODELS?



(Chen et. al., 1996, 1997; Chen and Dudhia, 2001; Ek et. al., 2003; Koren et. al., 1999)

- SWAT subsurface modeling capabilities are limited
- MODFLOW surface modeling capabilities are limited
- Evapotranspiration estimations are limited to site data availability



COUPLED : Models share fluxes at each time step. Feedback is important.
INTEGRATED: Models share fluxes in a batch fashion. Feedback is accounted.

WHY DO WE NEED A FRAMEWORK?

- SWAT and MODFLOW are conceptually different stand-alone models:
    - SWAT setup requires highly intense GIS data preparation carried out in ArcSWAT
    - MODFLOW setup requires highly intense GRIDs and text files formatting and processing commonly carried out by commercial applications
- Hydrologic modeling data preparation is time consuming (data screening, segregation, aggregation, interpolation, analysis, and formatting)
- GIGO: minimizing input data error and its propagation through the model is a priority

MODFLOW MODULES

Steady Stage
Time Variant

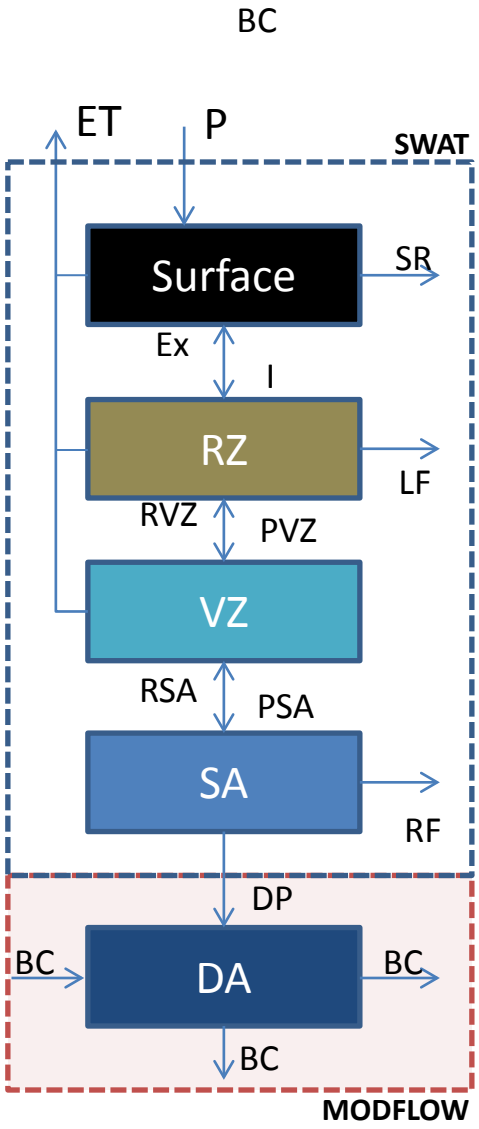
MODFLOW : 2000, 2005, LGR, CFP, NWT

MODFLOW$_{NWT}$ PACKAGES

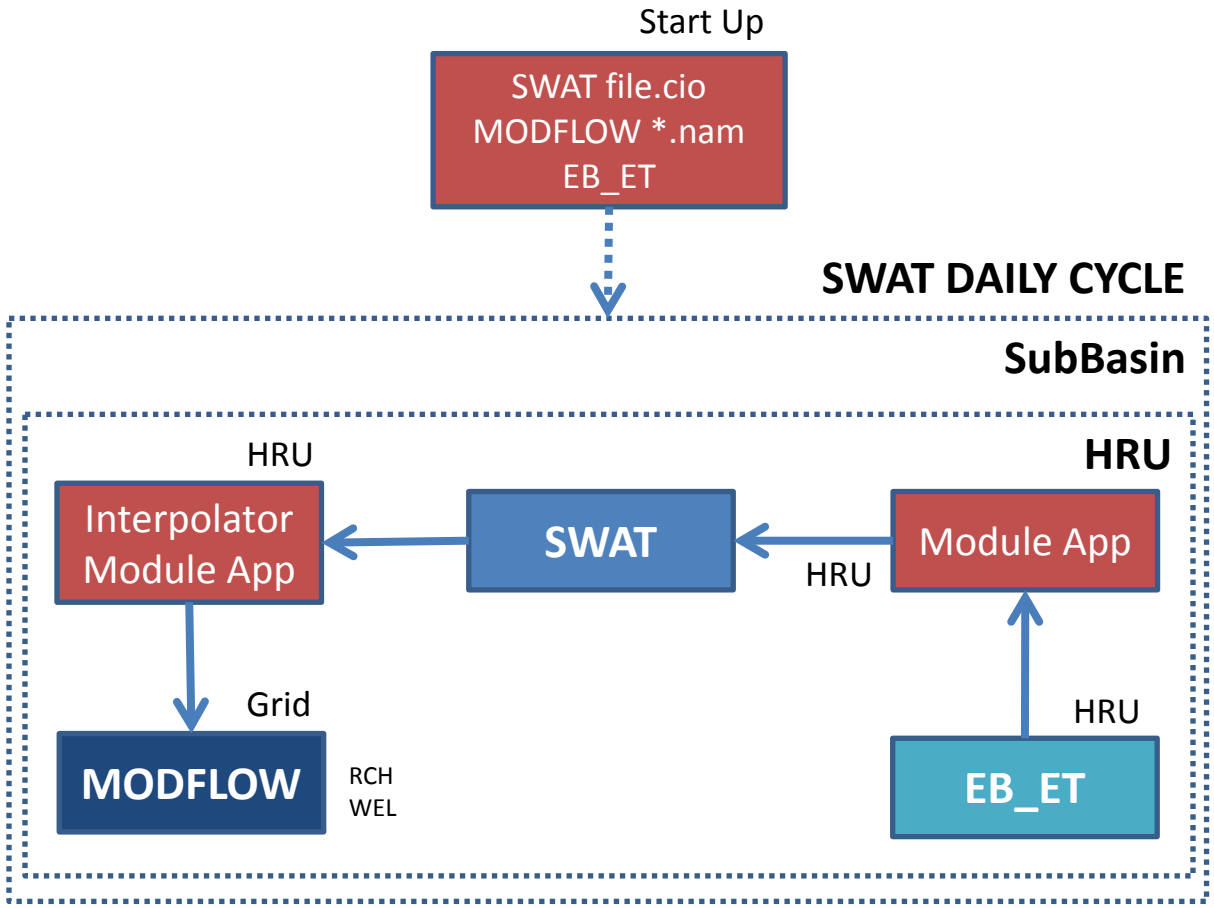
BAS6 : Basic package
BCF6 : Block-Centered flow package
CHD : Time-Variant Specified-Head package
CHOB: Specified-Head Flow Observation
DE4 : Direct Solver package
DIS : Discretization file
DRN : Drain package
DROB: Drain Observation input file
DRT : Drain Return Package
ETS : Evapotranspiration Segments Package
EVT : Evapotranspiration package
FHB :Flow and Head Boundary package
GAGE: Lakes and streams gaging stations
GBOB:General-Head-Boundary Obs.
GHB :General-Head Boundary package
HFB6 : Horizontal Flow Barrier package
HOB : Head-Observation input file
HUF2: Hydrogeologic Unit Flow package
IBS : Interbed-Storage package
KDEP :Hydraulic-Conductivity Depth-Dependence Capability
LAK : The Lake package
LVDA: Anisotropy direction
MNW: The Multi-Node, Drawdown-Limited Well package
NWT : Newton Solver
OC : Output Control Option
PCG : The Preconditioned Conjugate-Gradient package
RES : The Reservoir Boundary package
PVAL
RCH : The Recharge package
RIV : The River package
RVOB: The River Observation input file
SFR : The Streamflow-Routing package
SIP : The Strongly Implicit Procedure package
SUB : The Subsidence and Aquifer-System Compaction package
SWT :
UZF : Unsaturated Flow Package
UPW : The Upstream Weighting package
WEL : The Well package
ZONE: The Zone File

Transport Models

MT3DMS : Advection Dispersion Reaction (ADR) Transport Model
MODPATH : Particle Tracking Model



Roadmap I



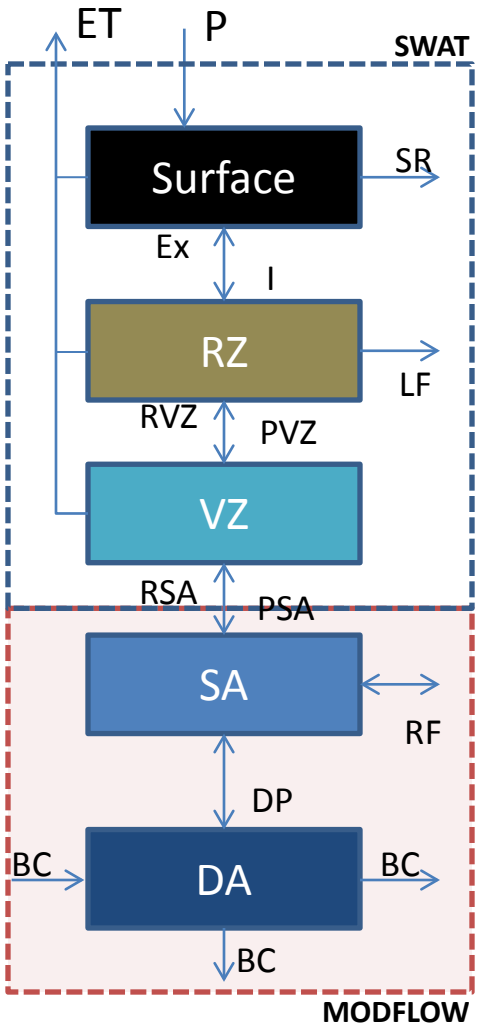
RZ = root zone
VZ = vadose zone
SA = shallow aquifer
DA = deep aquifer

SR = Surface Runoff
PVZ=percolation VZ
PSA=percolation SA
DP= deep percolation

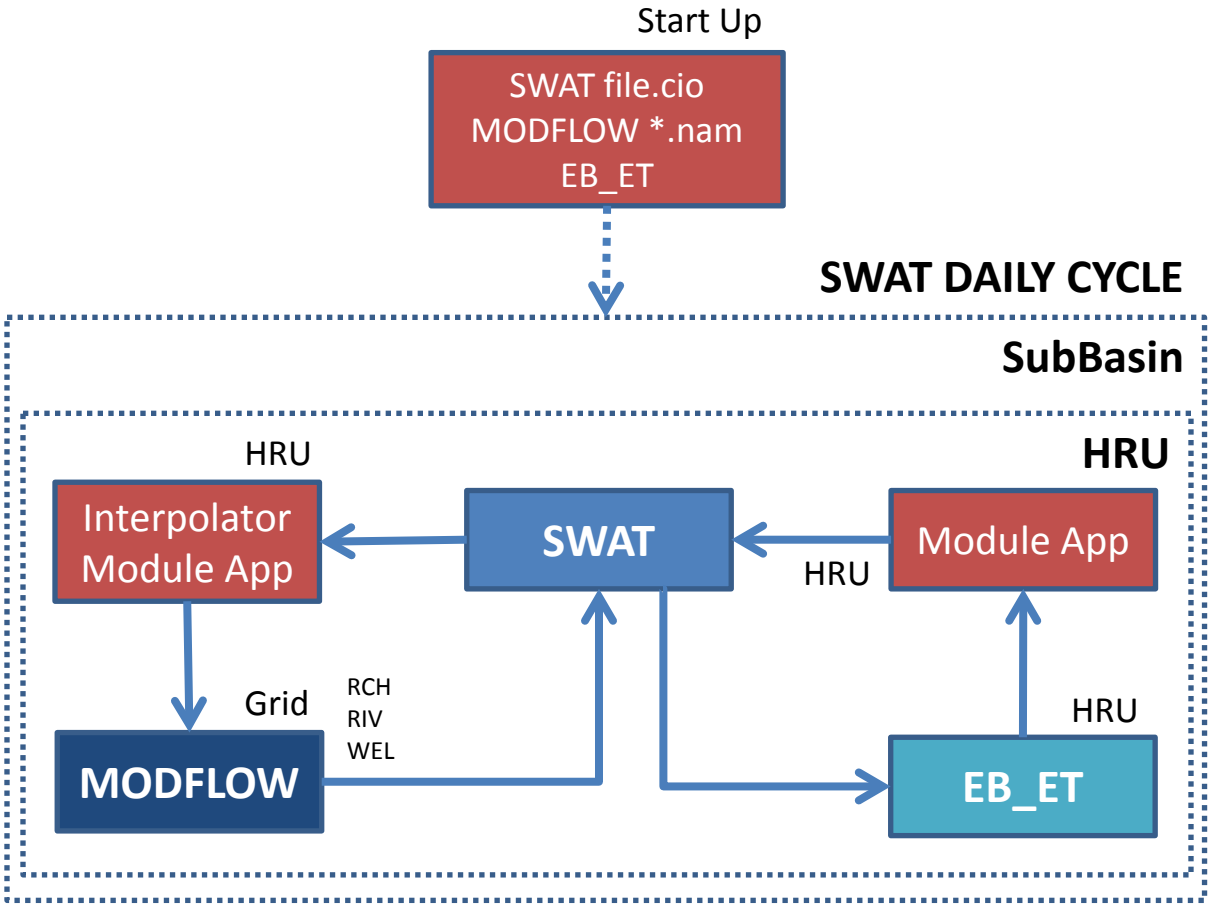
LF = lateral flow
RF = return flow

Ex = exfiltration
RVZ=return VZ
RSA=return SA

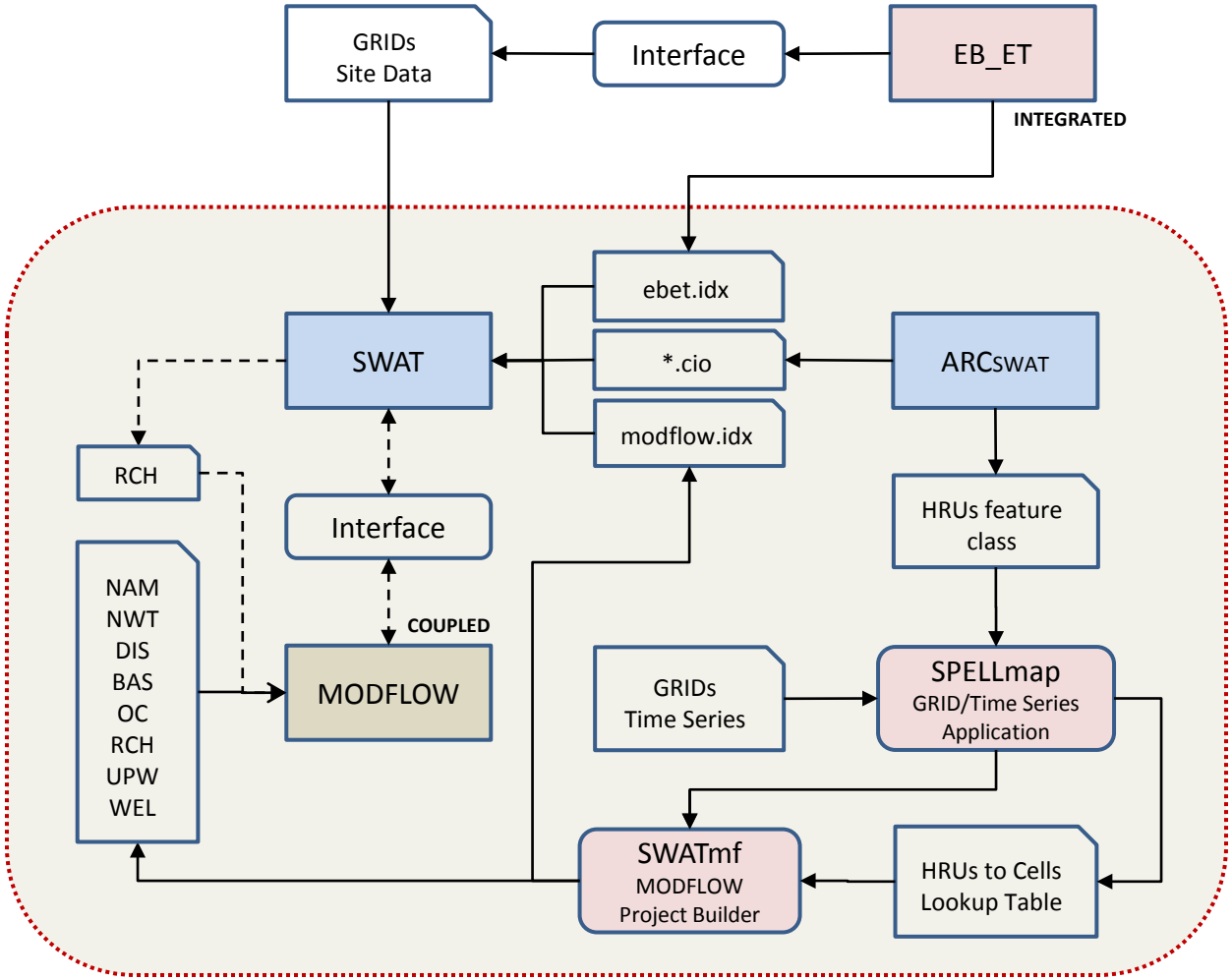
BC=boundary conditions


ET
P
SWAT
Surface
SR
Ex
I
RZ
LF
RVZ
PVZ
VZ
RSA
PSA
SA
RF
DP
BC
DA
BC
BC
MODFLOW

Roadmap II

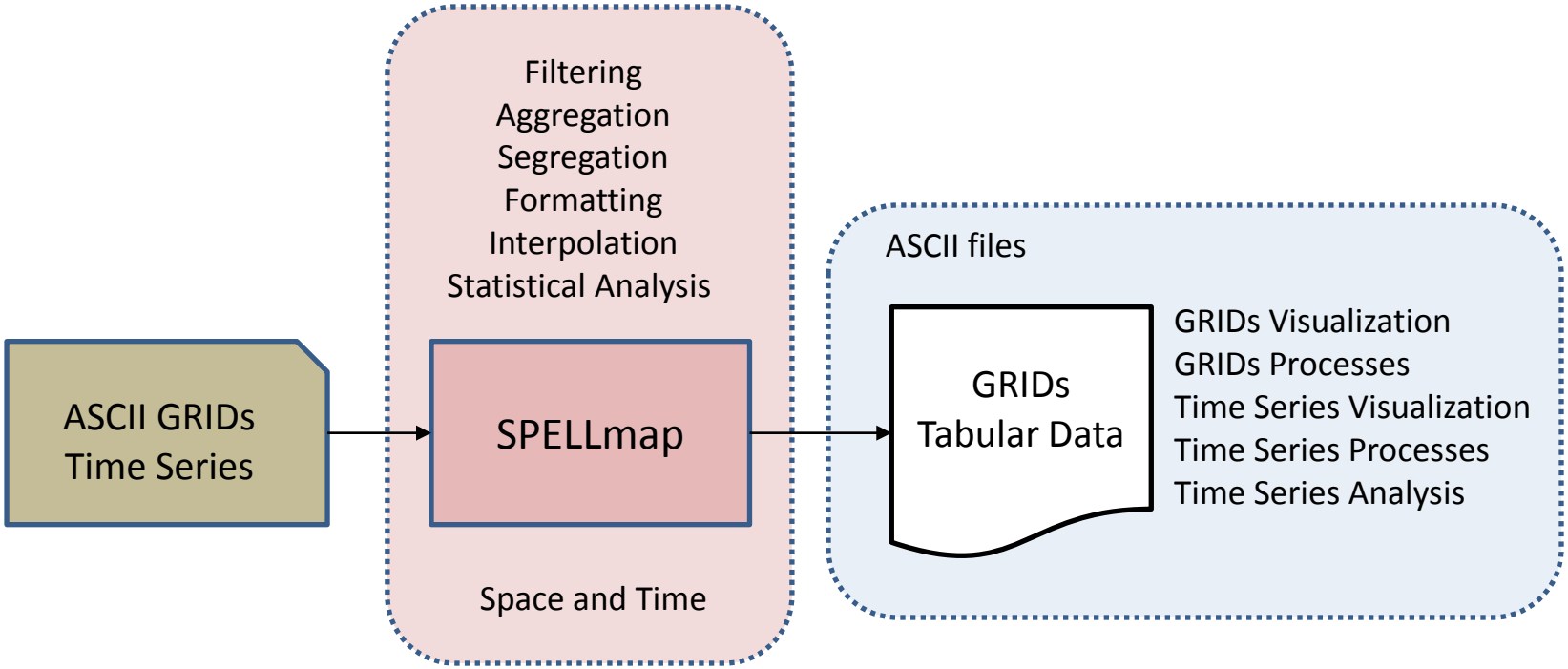

Start Up
SWAT file.cio
MODFLOW *.nam
EB_ET
SWAT DAILY CYCLE
SubBasin
HRU
HRU
Interpolator Module App
SWAT
Module App
HRU
Grid
RCH
RIV
WEL
HRU
MODFLOW
EB_ET

SWAT-MODFLOW Framework



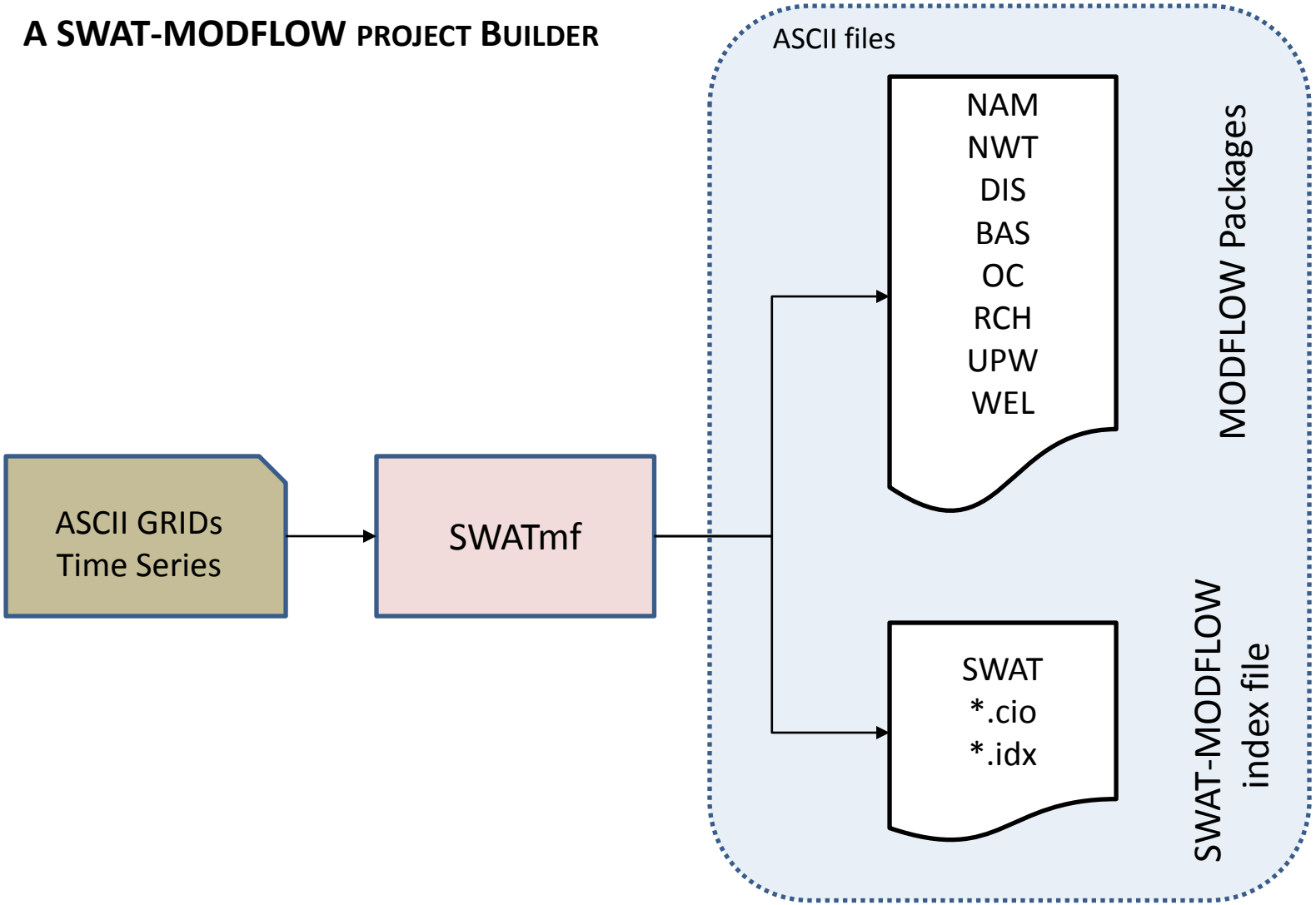
SPELLmap Application

MAPPING AND ANALYSIS TOOL FOR SPATIAL TIME SERIES AND SPATIAL DISTRIBUTED DATA



SWATmf Application

A SWAT-MODFLOW PROJECT BUILDER

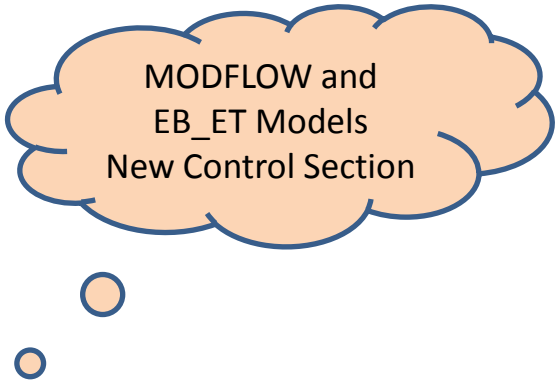


SWAT model

Hey… did you notice there are new guys in the party?

SWAT INPUT FILE: *.cio

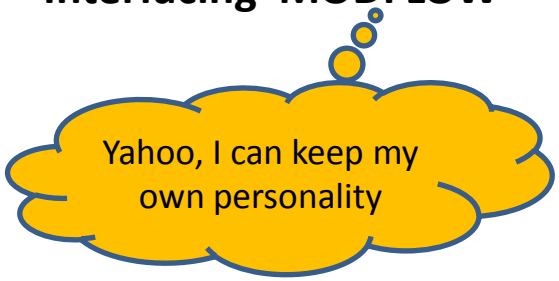
```
Reach output variables:
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
Subbasin output variables:
  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
HRU output variables:
  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
HRU data to be printed:
  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
COUPLED MODELS:
ModFlow.idx                | MODFLOW index file
        1                  | MODFLOW: 0=no coupled, 1=coupled
EB_ET.idx                  | EB_ET index file
        0                  | EB_ET: 0=no coupled, 1=couple
ATMOSPHERIC DEPOSITION
ATMO.ATM
        0    | IPHR: print code for hourly output 0=no 1=yes
(hourq.out)
        0    | ISTO: print code for soil storage 0=no 1=yes (soilst.out)
        0    | ISOL: Code for printing phosphorus/nitrogen in soil
profile (output.sol)
        0    | I_SUBW: Code for routing headwaters
```



← MODFLOW index file name and path

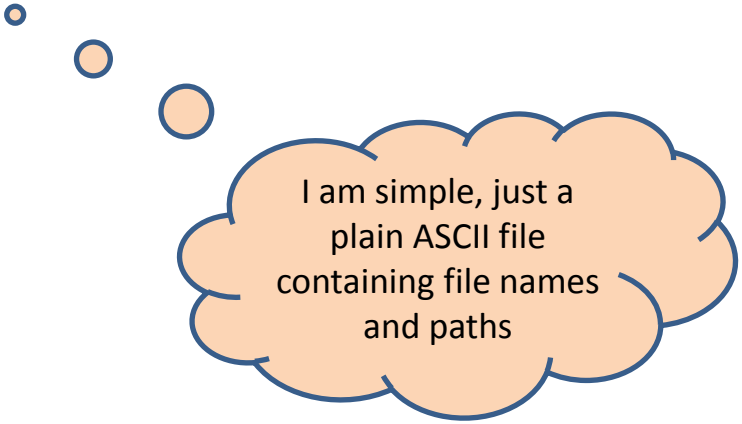
← EB_ET index file name and path

Interfacing MODFLOW



MODFLOW index file … SWATmf will do it for you

```
# ----------------------------------------------------------------------------
#         MODFLOW index file by ARS-USDA Grazingland Research Laboratory
# ----------------------------------------------------------------------------
# Use full PATH for files (items 3,4 and 5); max=79 characters
# 6/27/2012 4:09:19 PM
c:\ars\delphi\swatmf\win64\test\                                  | 1. MODFLOW project folder
SWATmf                                                            | 2. MODFLOW nam file (path and extension no included)
c:\ars\delphi\swatmf\win64\test\lookupTable.idx                   | 3. HRUs to MODFLOW lookup table
C:\ARS\DELPHI\SWATmf\Win64\test\SWATmf\hruIDs.txt                 | 4. HRUs ID grid from feature class
C:\ARS\DELPHI\SWATmf\Win64\test\SWATmf\FC90x90MFmask.txt          | 5. MODFLOW extent grid
LIST            c:\ars\delphi\swatmf\win64\test\SWATmf.lst
BAS             c:\ars\delphi\swatmf\win64\test\SWATmf.bas
DIS             c:\ars\delphi\swatmf\win64\test\SWATmf.dis
NWT             c:\ars\delphi\swatmf\win64\test\SWATmf.nwt
UPW             c:\ars\delphi\swatmf\win64\test\SWATmf.upw
RCH             c:\ars\delphi\swatmf\win64\test\SWATmf.rch
WEL             c:\ars\delphi\swatmf\win64\test\SWATmf.wel
```

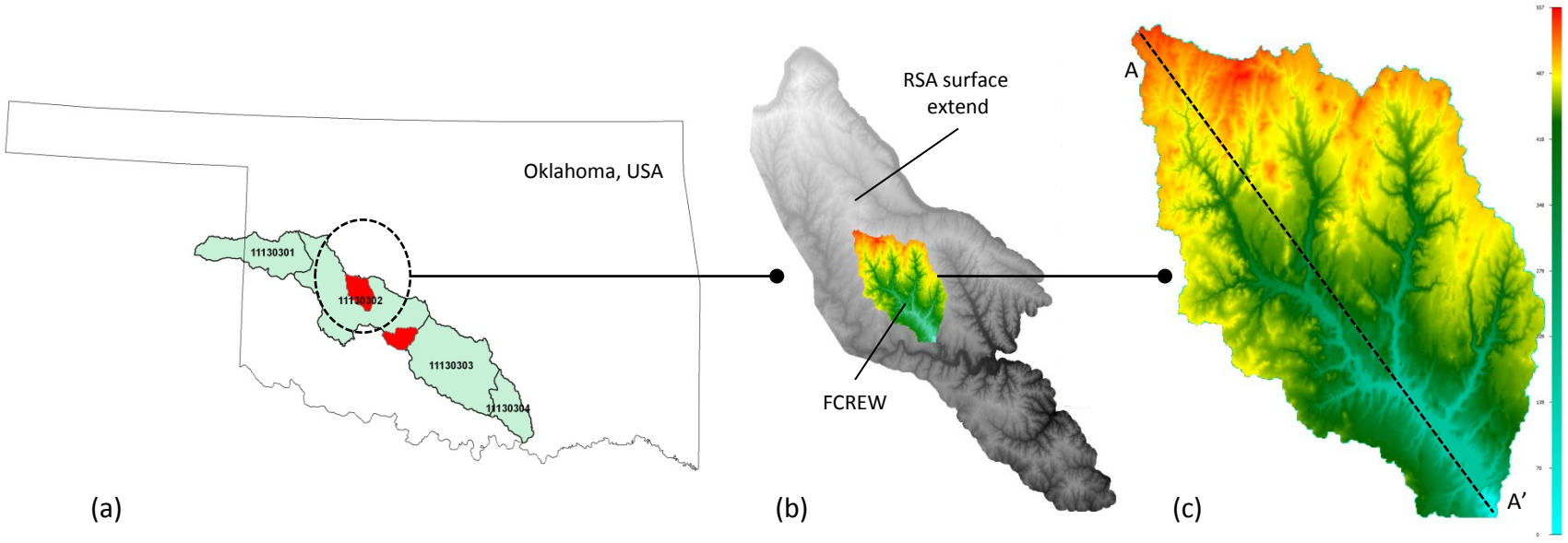


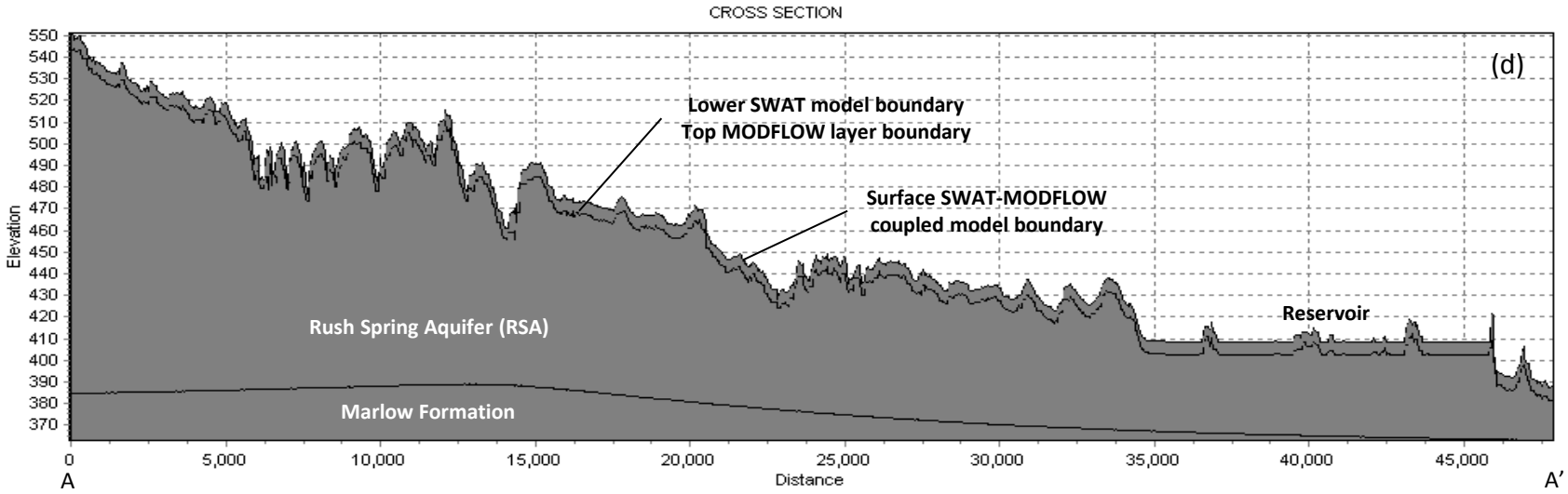
Coupling MODFLOW

Where should I start if I want to couple SWAT and MODFLOW?

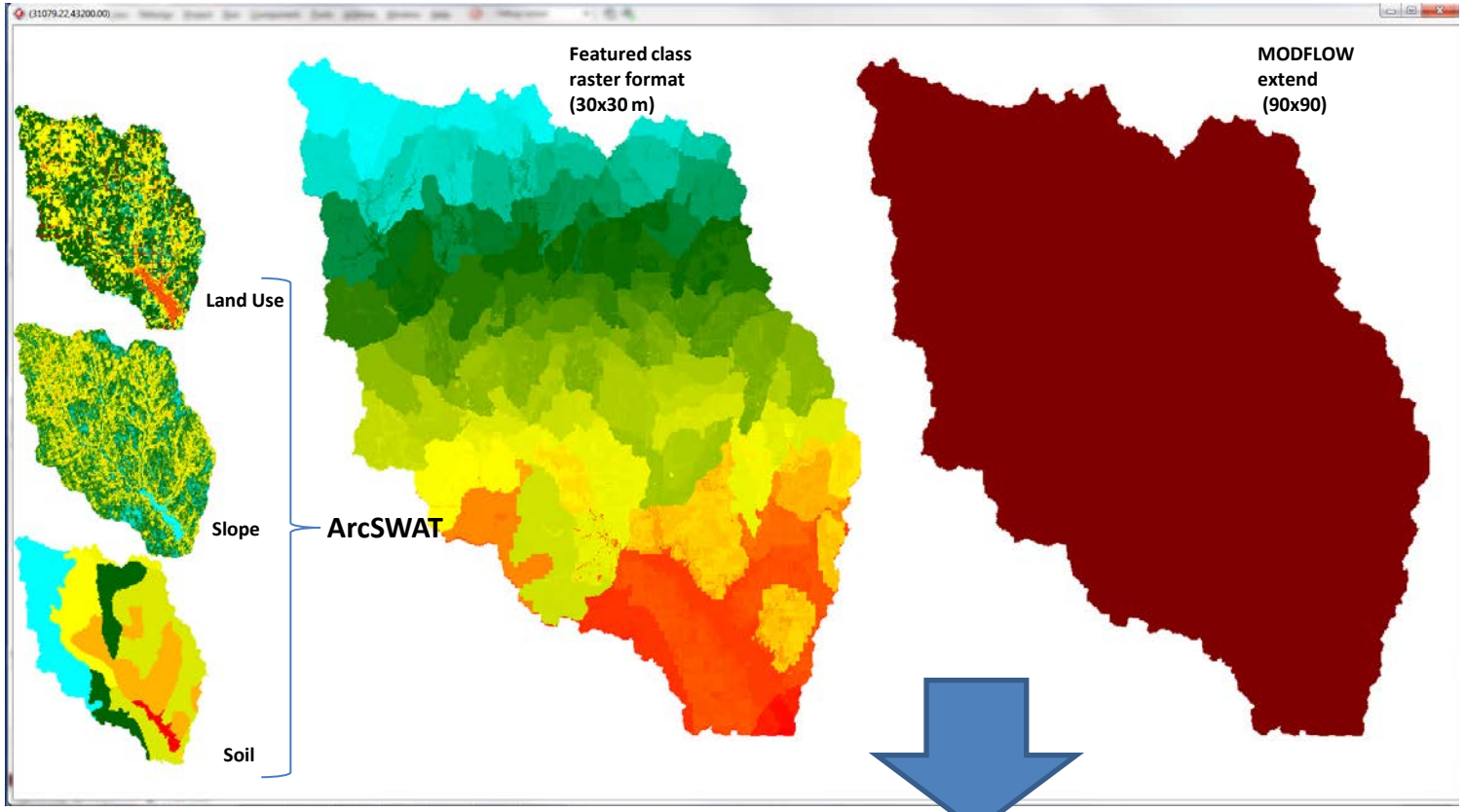
1. Be sure your time series and GRIDs are in a good shape (data screening)
   use SPELLmap
2. Build your SWAT project to running stage
   use ArcSWAT
3. Build your MODFLOW project to running stage
   use SPELLmap or your fancy application
4. Setup the coupled SWAT and MODFLOW model
   use SWATmf
5. Be brave, this is not going to be easy

SPELLmap Application





SPELLmap Application

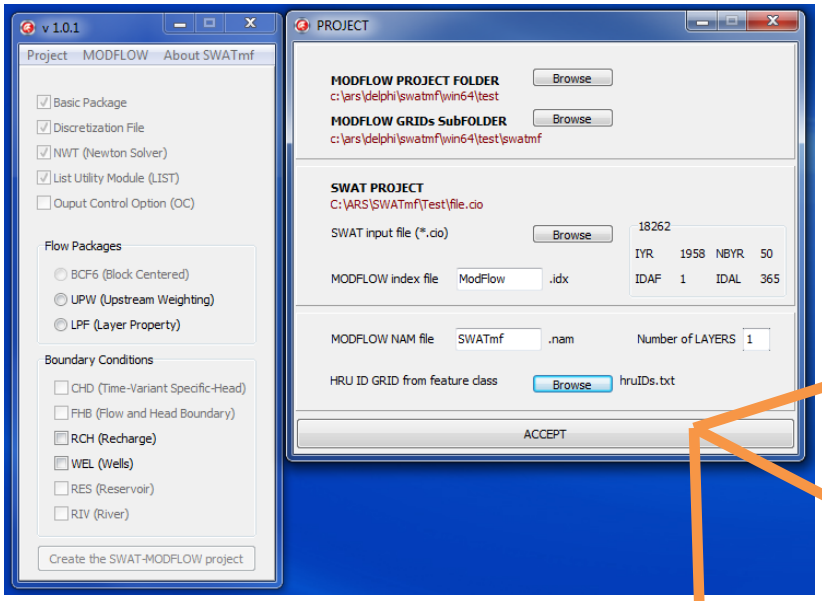


Lookup Table (Text File)

HRUid	DEMid	MFid	Area Fraction
1	75259	8811	0.102609287778398
1	75259	8412	0.00850182333271261
2	75260	8811	0.0994592918198918
2	75260	8412	0.00824082640233901
2	75260	8413	0.000260996930373597
2	75260	8812	0.00314999595850674
2	75261	8812	0.102609287778398

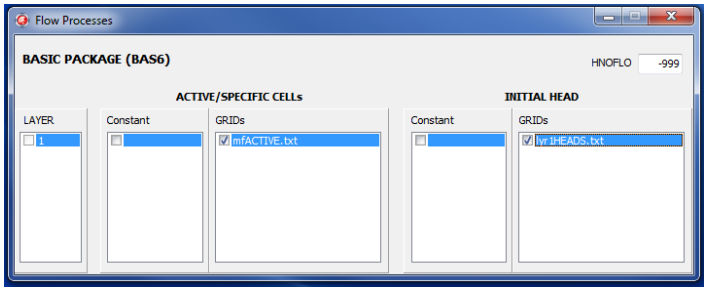
SWAT-MODLOW

An Integrated Hydrologic Modeling Framework For Coupling SWAT With MODFLOW

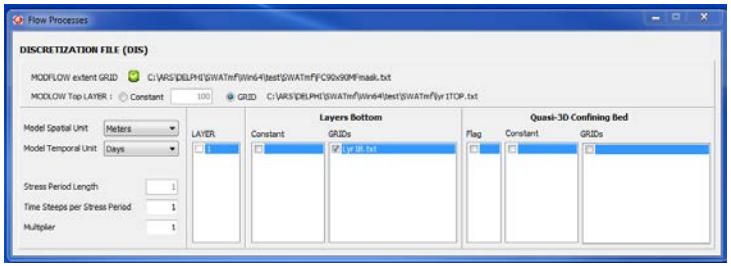


SWATmf Application

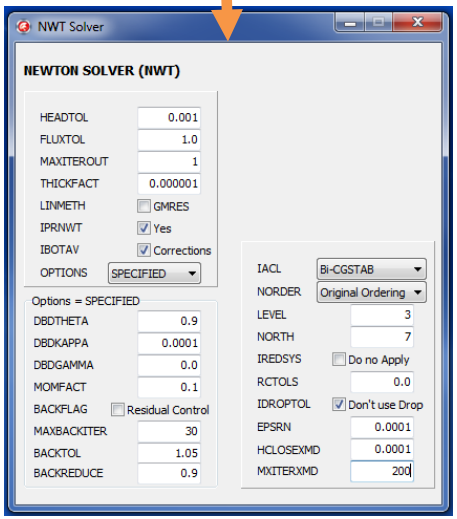
BAS



DIS



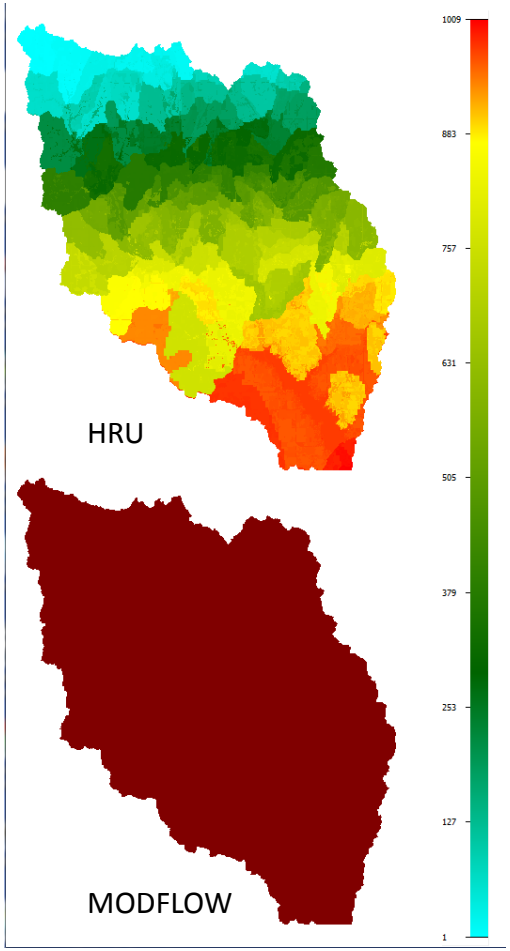
NAM
NWT
DIS
BAS
OC
RCH
UPW
WEL

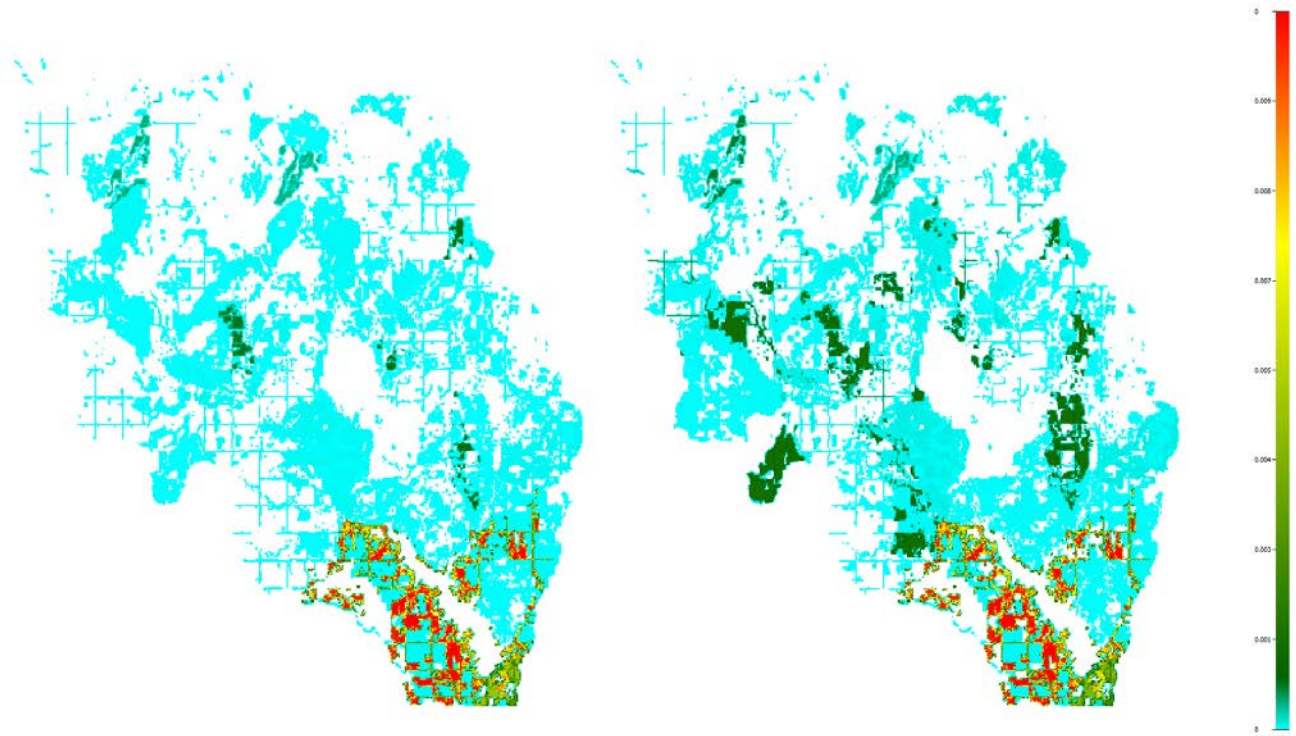


NWT

```
# Created by SWATmf an ARS-USDA GRL app v 1.0.1
# Newton Solver (NWT)
# 6/29/2012 4:28:52 PM
#
0.001 1.0 1 1.0E-006 2 1 1 SPECIFIED 0.9 0.0001 0.0 0.1 0 30 1.05 0.9
2 0 3 7 1 0.0 0 0.0001 0.0001 200
```

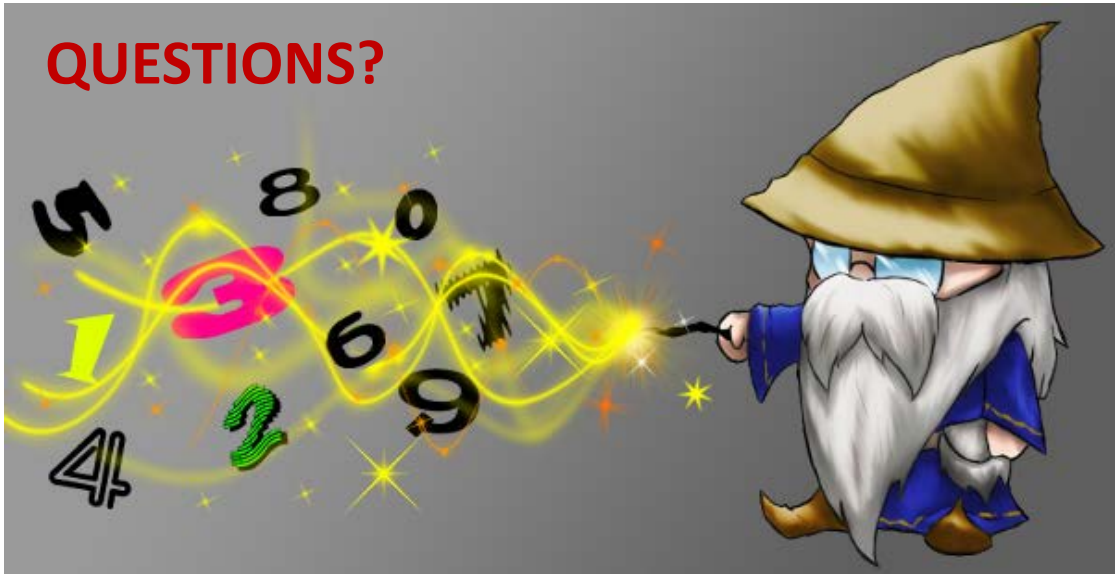
COUPLED SWAT-MODFLOW





Recharge Fluxes
Simulation Day: 162

Recharge Fluxes
Simulation Day: 421


QUESTIONS?