Comparison of runoff responses between SWAT and sequentially coupled SWAT-MODFLOW model

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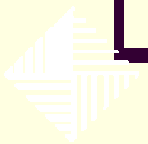


Background

- Sustainable Water Resources Research Cenetr
  - future water shortage problem
- Poor assessment of continuous runoff process
  - lumped model widely used in Korea
- Increased groundwater usage
  - 2.6 billion m^3/yr (1995) ➡ 3.7 billion m^3/yr (2003)
- Stream depletion problem

Goals

- To develop a method for simulating water balance considering the water exchange between stream and aquifer at various scales
- To evaluate the predictive capability of SWAT with other integrated watershed models in simulating long-term runoff response in Korea

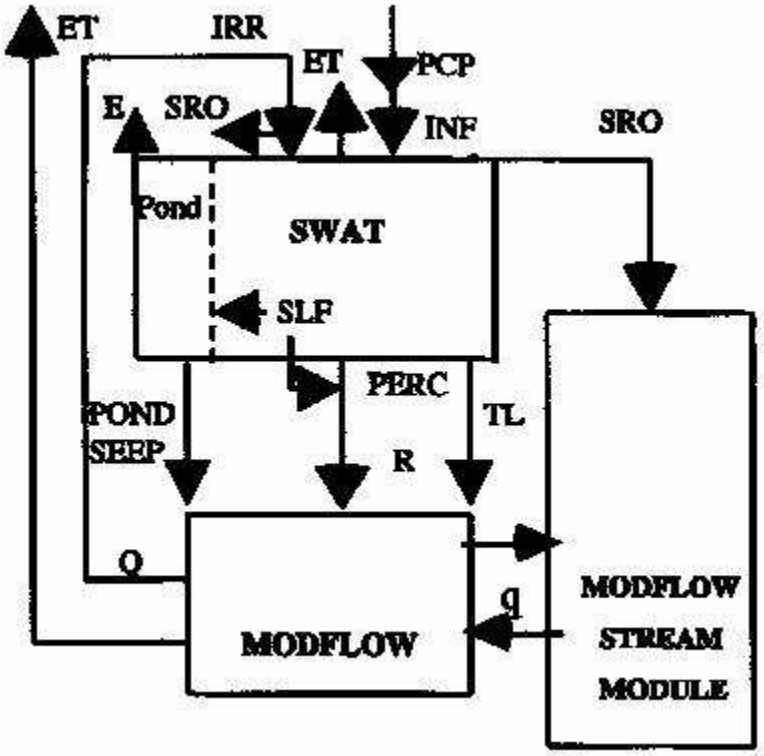
Limitations of SWAT

- Integrated model for surface and subsurface water
- Difficult to estimate stream-aquifer water exchange due to pumping
- Difficult to estimate the spatial and temporal distribution of groundwater table
- Difficult to consider the impact of deep and complex aquifer system on baseflow response

Ground water model

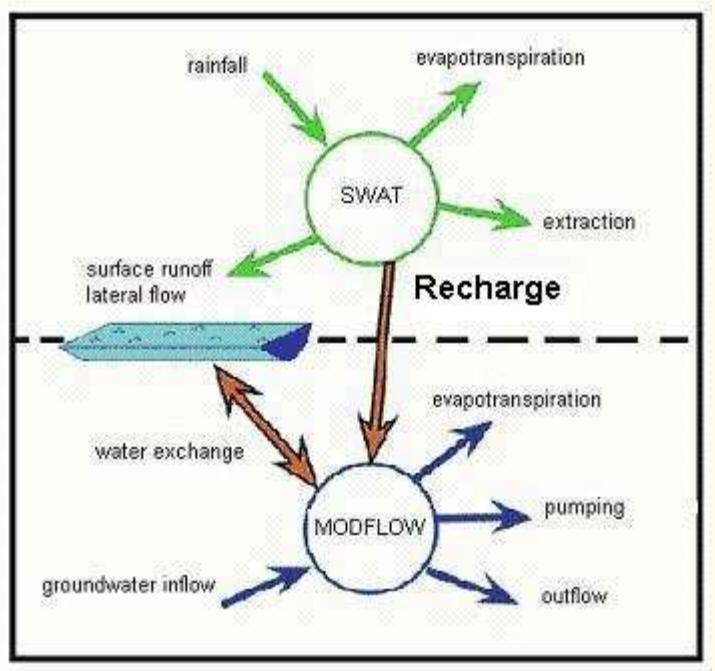
- MODFLOW developed by USGS
- Cell based 3D finite difference method
- Widely used public domain program
- Modular structure with various packages

SWAT-MODFLOW combined model (Perkins and Sophocleous, 1999)



PCP_precipitation
INF_infiltration
ET_evapotranspiration
IRR_irrigation
E_evaporation
SLF_subsurface lateral flow
PERC_percolation
R_recharge
TL_transmission losses
Q_ground-water pumping
POND SEEP_pond seepage
q_stream seepage

Sequential coupling approach



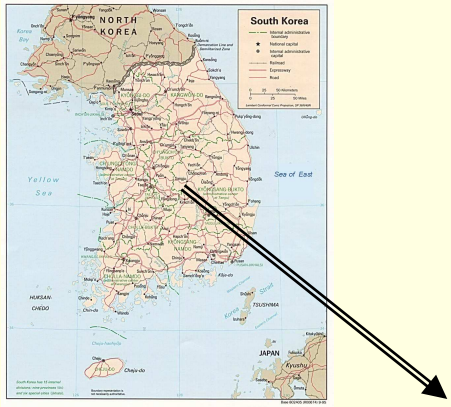
Advantages

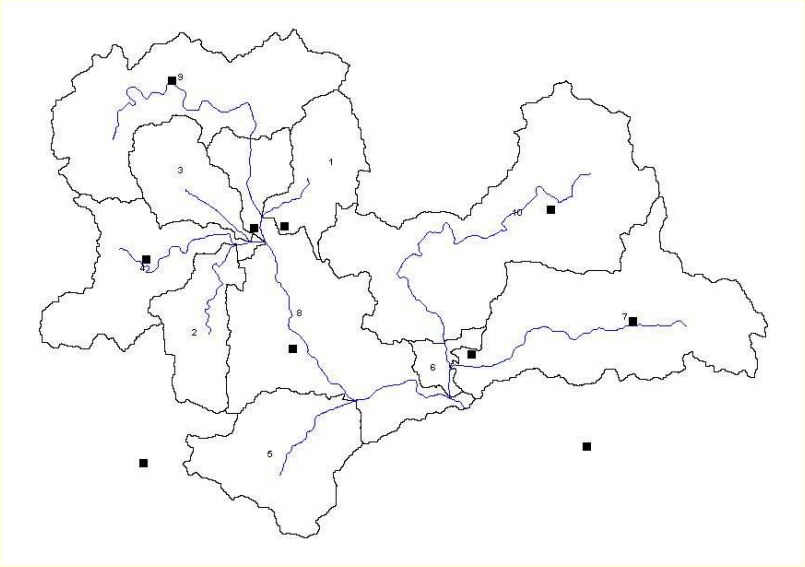
1. Separate simulation
2. No interface code
3. Conceptually simple

Problems

1. Scale problem
2. Lack of dynamic interaction between stream stage and ground water level

Bocheong-chun IHP watershed





Area =353 km^2

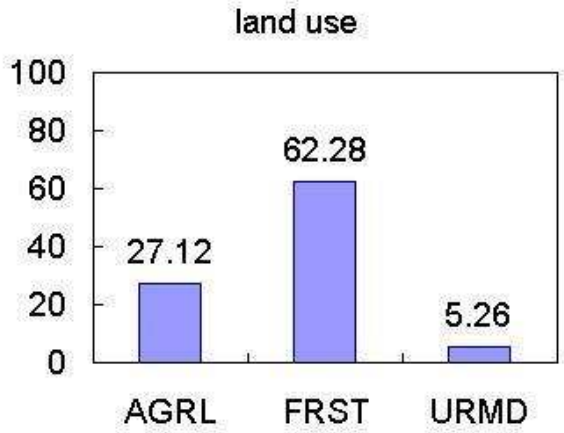
11 rain gauges

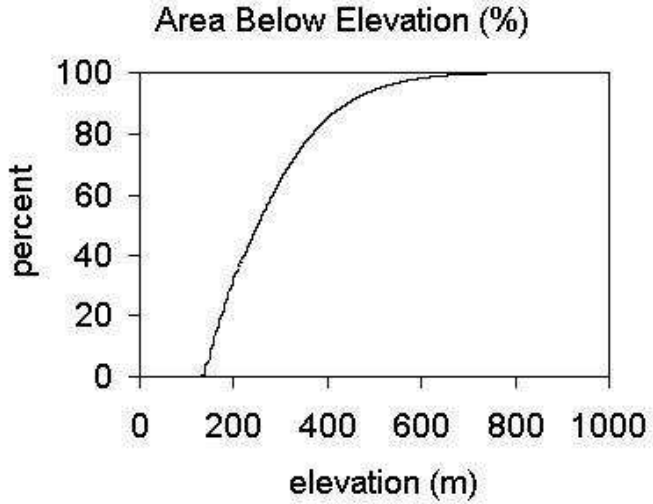
4 water level stations

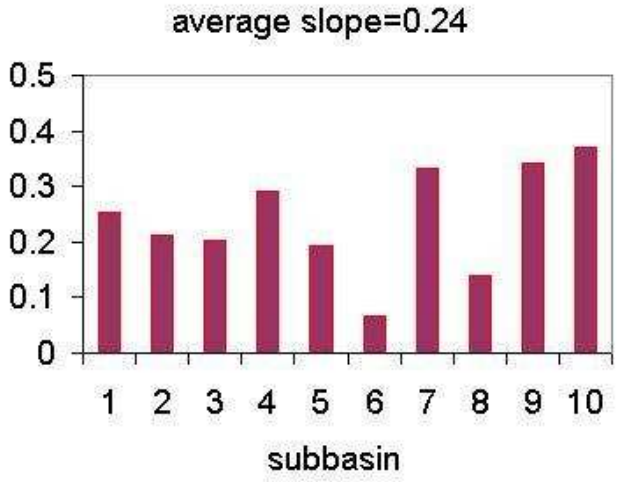
Geology

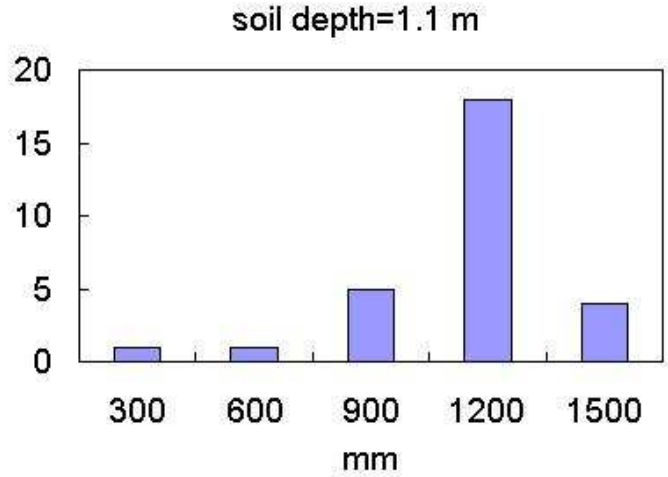
Sandstone

Granite

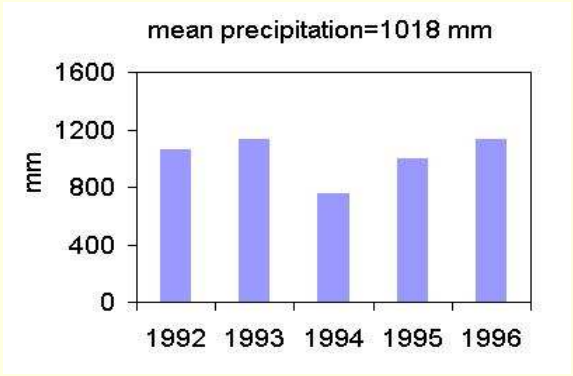

land use
100
80
60
40
20
0
27.12
62.28
5.26
AGRL
FRST
URMD

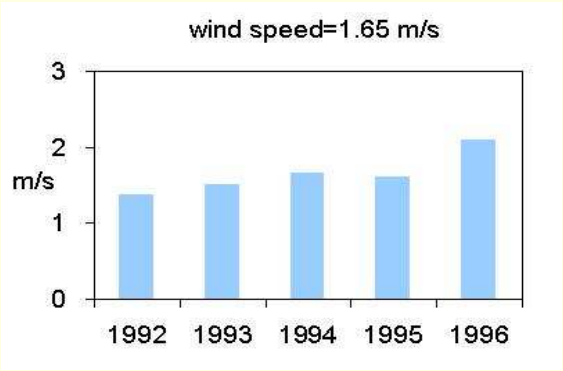

Area Below Elevation (%)
percent
100
80
60
40
20
0
0
200
400
600
800
1000
elevation (m)

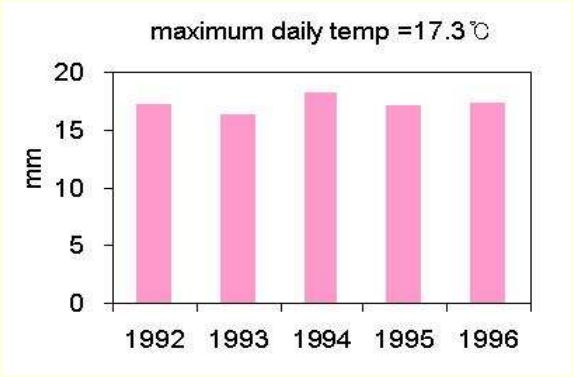

average slope=0.24
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
7
8
9
10
subbasin

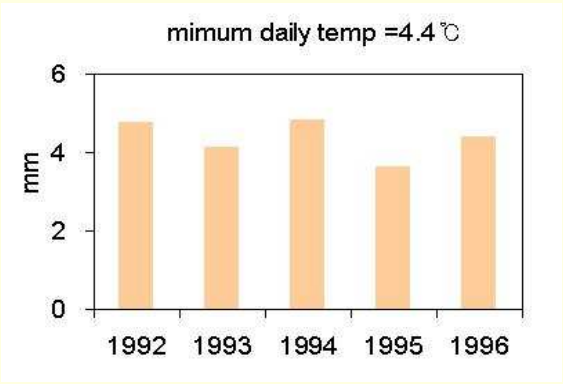

soil depth=1.1 m
20
15
10
5
0
300
600
900
1200
1500
mm

SWAT simulation

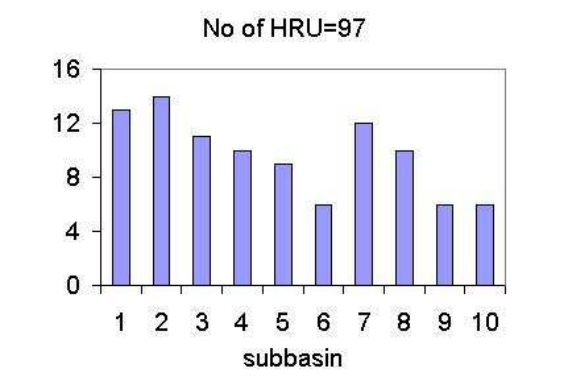


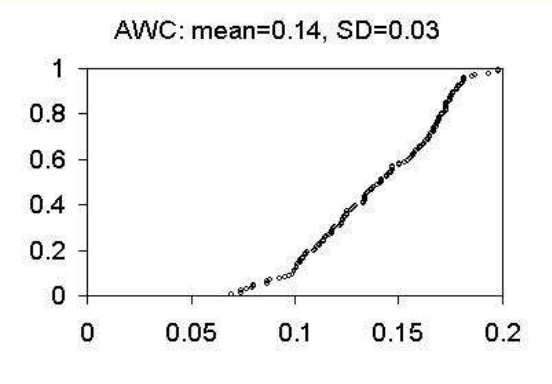


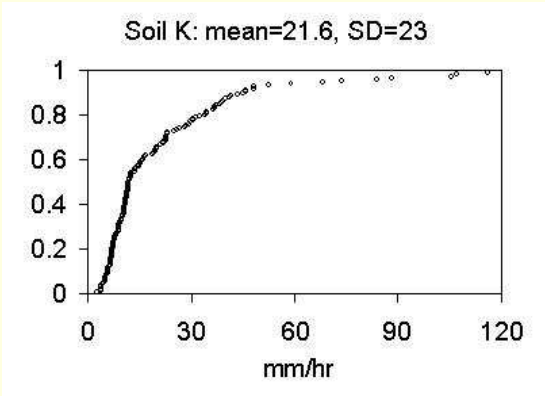


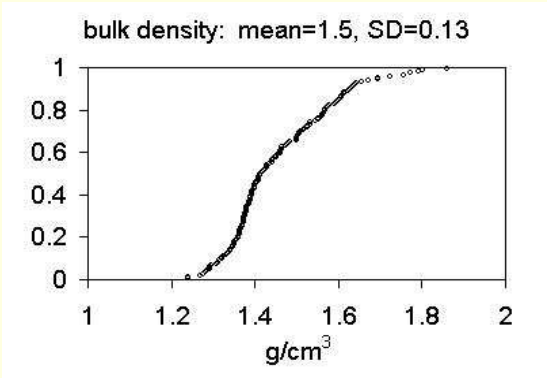


SWAT simulation



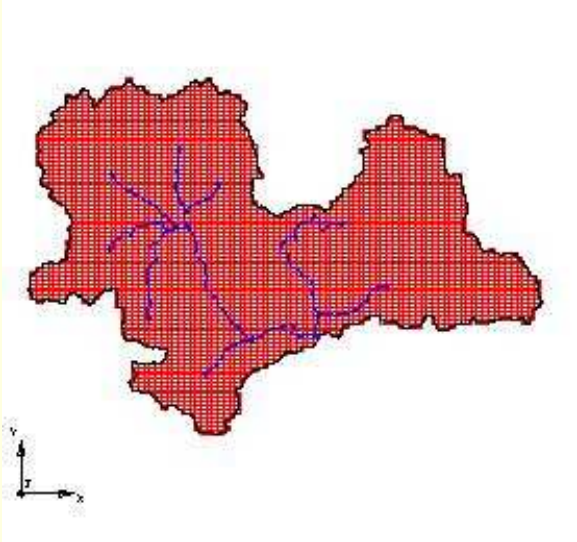






MODFLOW simulation

- 100 columns, 100 rows, 1 layer
- Surface water and ground water divide coincide
- River package, Recharge package
- National Groundwater Information Management and Service Center: limited groundwater DB available



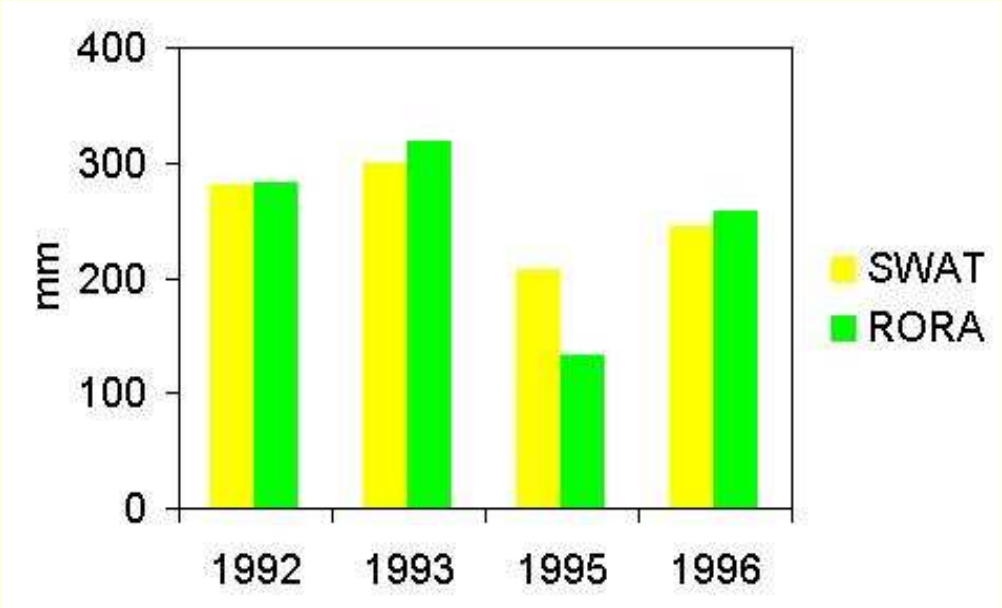
Model Calibration

- Manual calibration

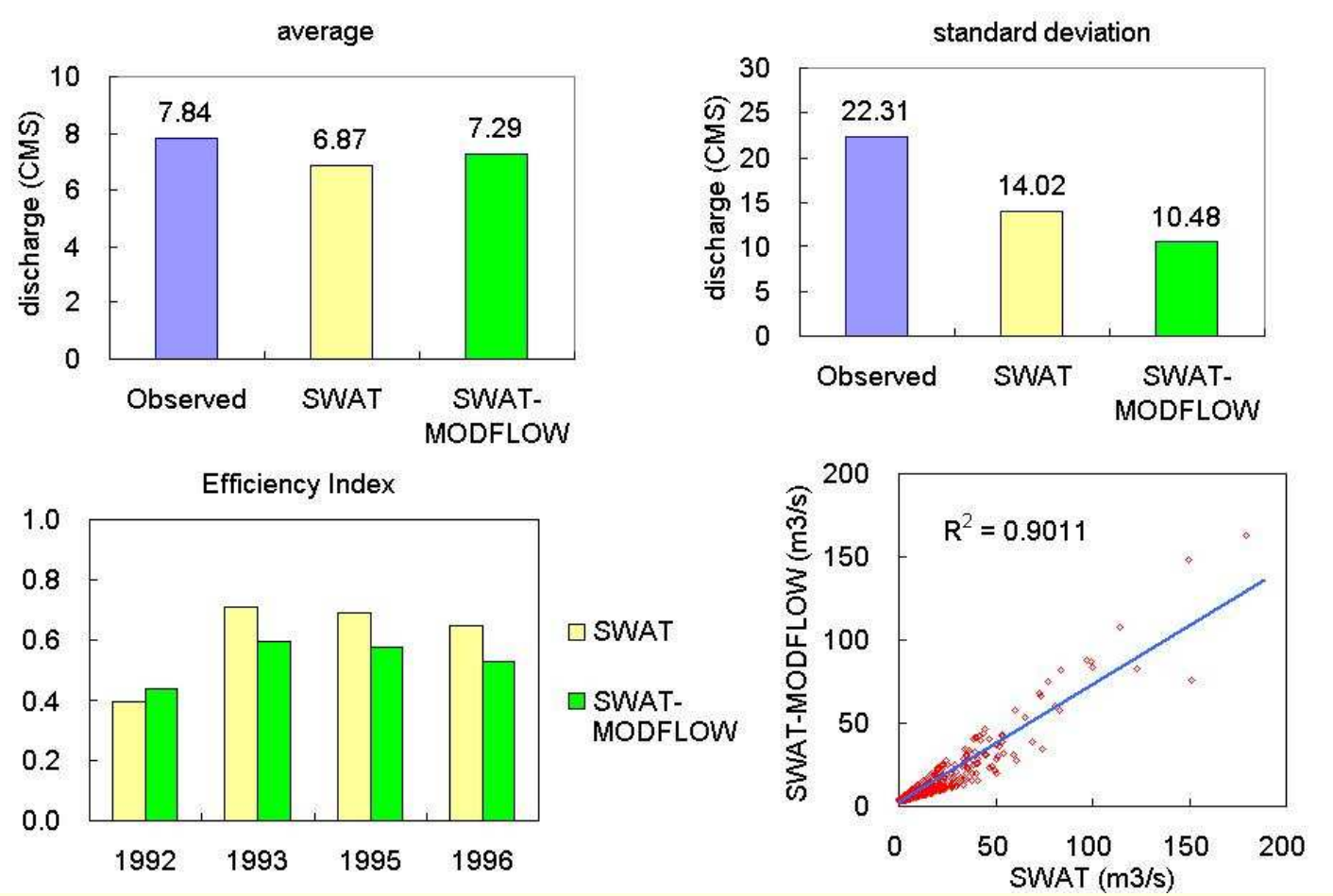
- SWAT model
  - GW_DELAY, ALPHA_BF, REVAPMN
  - CN2, CH_N1, CH_N2, ESCO

- MODFLOW model
  - hydraulic conductivity
  - river bed conductance
  - aquifer depth

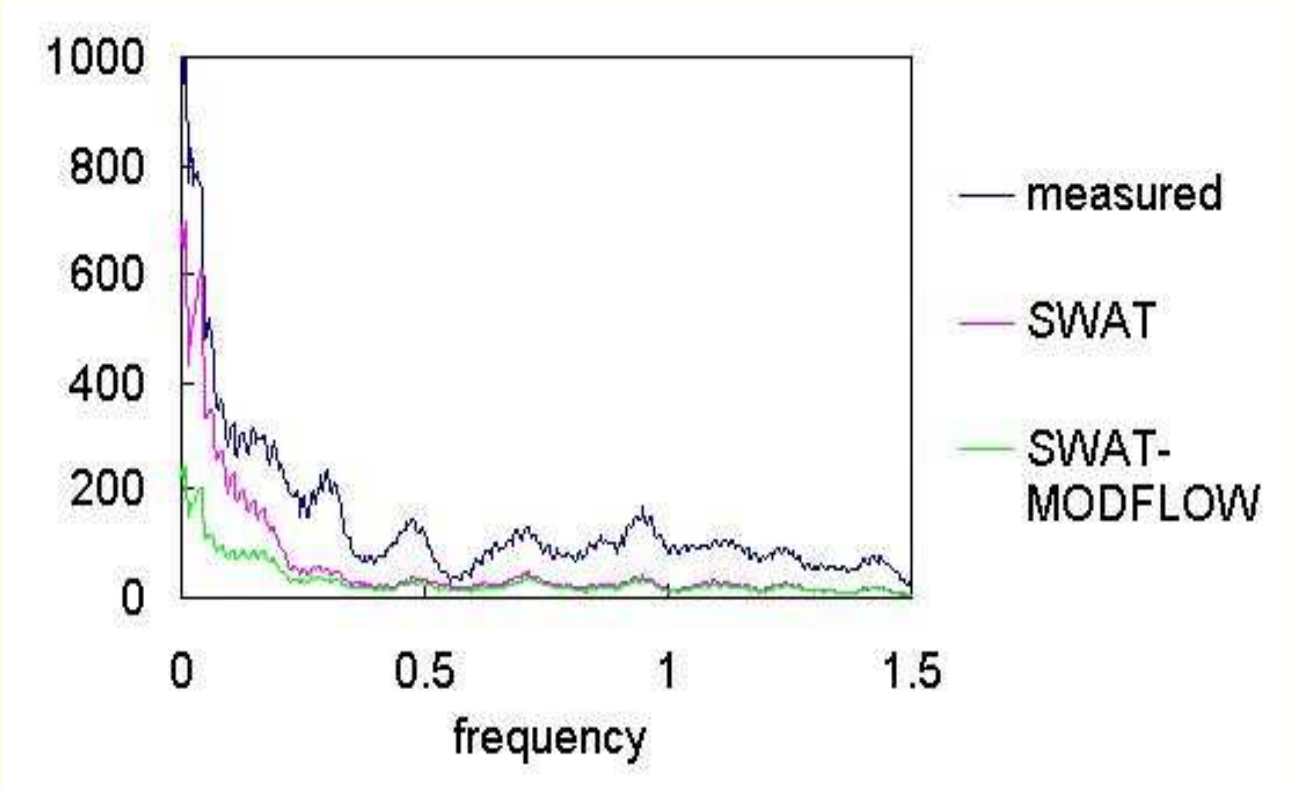
Annual recharge comparison



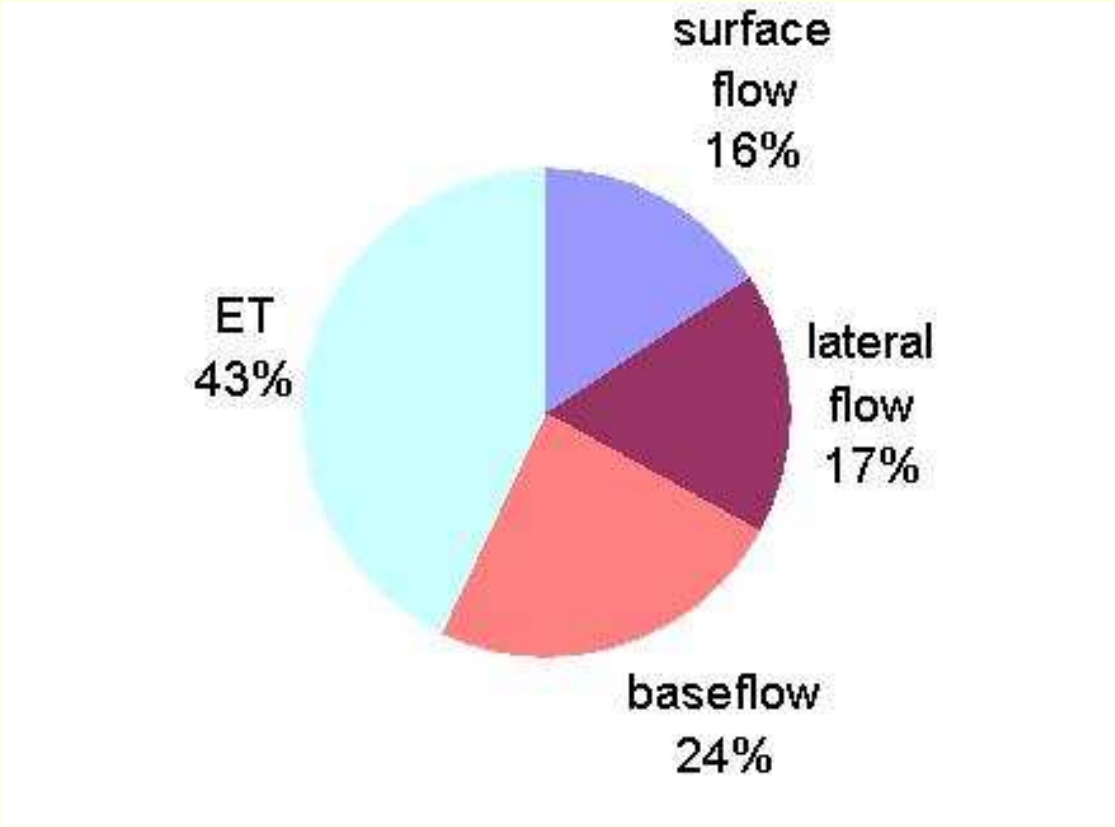
Daily discharge



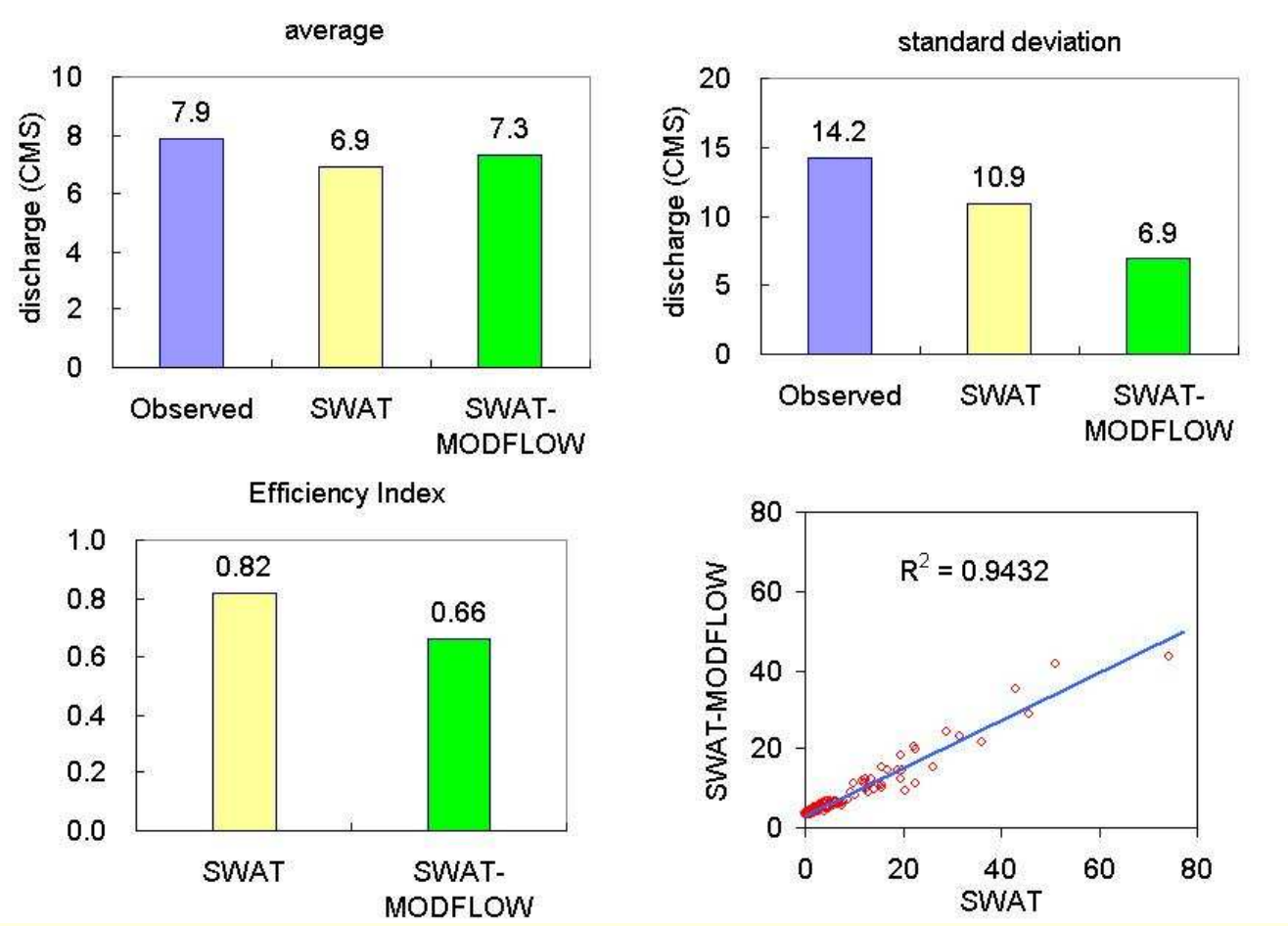
Periodogram for daily record



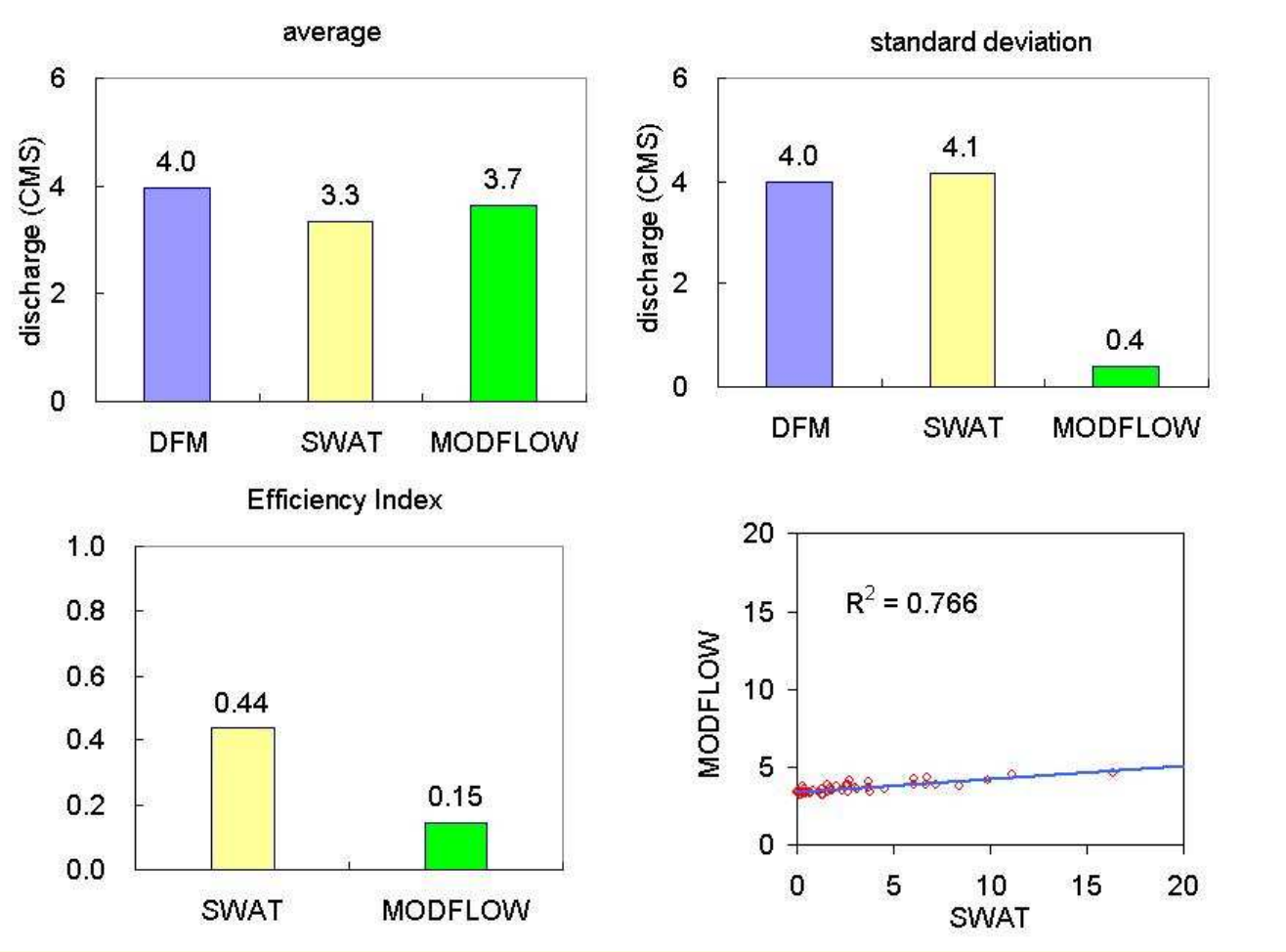
Average Annual Water Budget



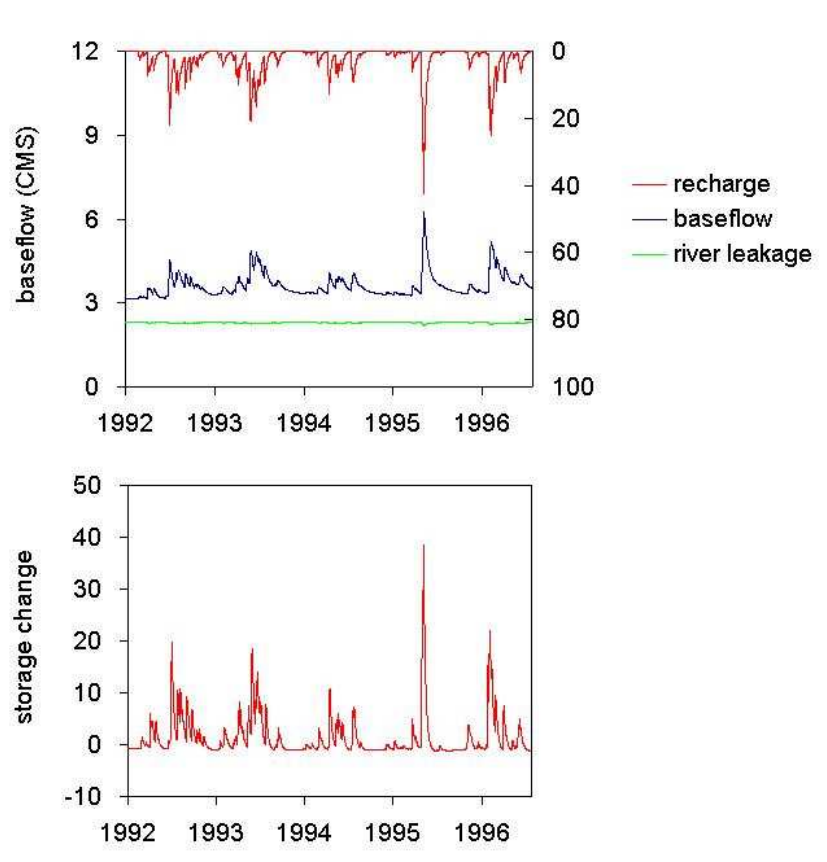
10 day averaged discharge

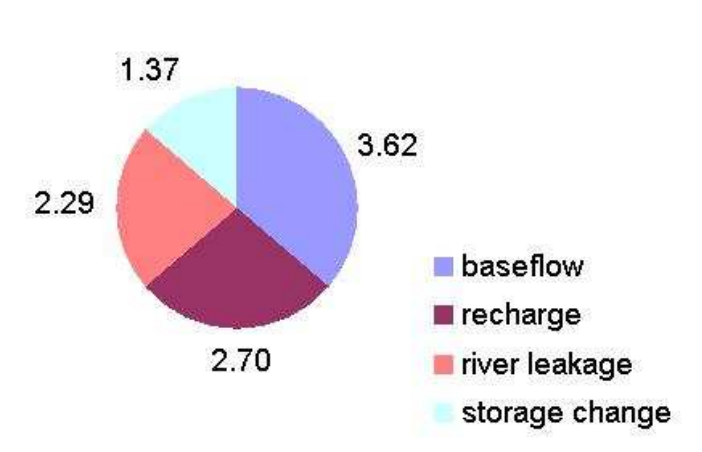


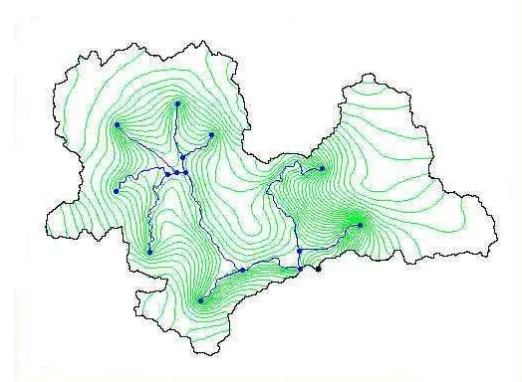
Monthly baseflow



Ground water budget







Conclusions

- Performance of SWAT in predicting daily discharge is fair(EI=0.66), but that of SWAT-MODFLOW is poor(EI=0.54).
- Variance of two model outputs underestimated those of measured discharge, while average of model output agrees with measured discharge.
- Performance of two models increases as output response time scales increase.

Conclusions

- Large difference of baseflow variability between SWAT and MODFLOW
- SWAT-MODFLOW sequentially coupled model contains large uncertainty of model response due to uncertain aquifer characteristics, initial and boundary conditions, but is useful for estimating the detailed ground water balance and ground water level.

Ongoing and future research

- To test with the SWAT-MODFLOW dynamic coupling developed by KICT
- To test with other integrated models
  (e.g. MIKESHE, HSPF-MODFLOW)
- Over-parameterization/Non-unique problem? Need to develop rigorous calibration method using internal variables and uncertainty analysis for the coupled model

Questions or Comments?

Thank you for your attention.