Comparison of Grid-based and SWAT HRU Modeling Approaches for Evaluating the Climate Change Impact on Watershed Hydrology

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JUNG, Hyuk
Graduate Student

HONG, Woo-Yong / Jeong, Hyeon Gyo
Researcher / Meteorological Research Scientist

KIM, Seong-Joon
Professor

KONKUK UNIVERSITY

Dept. of Civil and Environmental System Eng.,
Konkuk University, Seoul, South Korea

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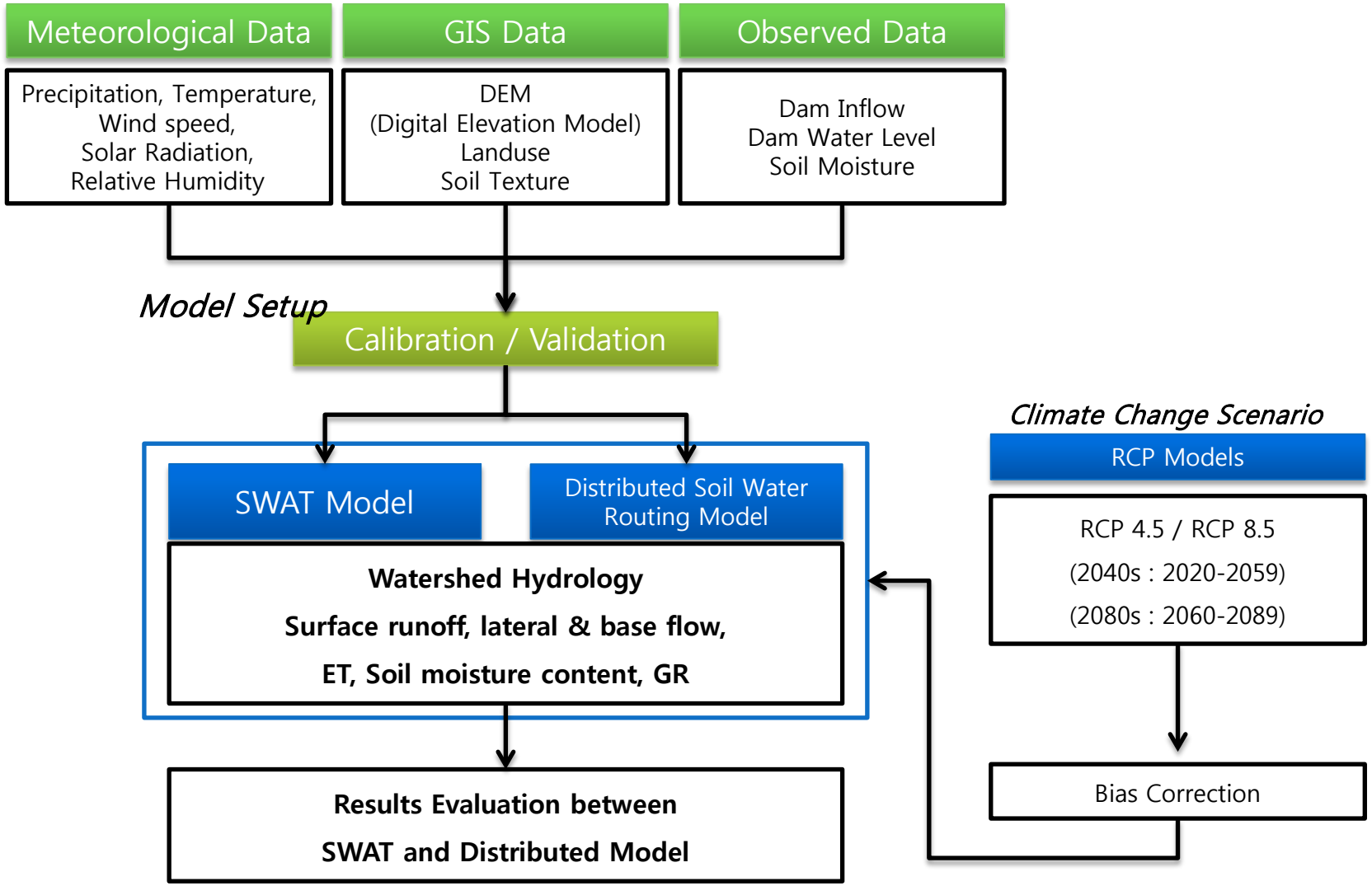
Purpose

- Hydrology model started from lumped model such as HEC-HMS has been developed to HRU distributed model such as SWAT and SLURP, and cell-based distributed model such as VIC and Vflo™.

- Distributed model has advantages to represent and understand the happenings of hydrological behavior in the watershed.

- For climate change impact assessment on hydrology of South Korea, we are trying to develop a model, grid-based continuous hydrological model.

- In this study, we are presenting our model in developing stage and validate the modeling efficiency comparing with SWAT results.


Meteorological Data
GIS Data
Observed Data
Precipitation, Temperature,
Wind speed,
Solar Radiation,
Relative Humidity
DEM
(Digital Elevation Model)
Landuse
Soil Texture
Dam Inflow
Dam Water Level
Soil Moisture
Model Setup
Calibration / Validation
SWAT Model
Distributed Soil Water Routing Model
Watershed Hydrology
Surface runoff, lateral & base flow,
ET, Soil moisture content, GR
Results Evaluation between
SWAT and Distributed Model
Climate Change Scenario
RCP Models
RCP 4.5 / RCP 8.5
(2040s : 2020-2059)
(2080s : 2060-2089)
Bias Correction

Soil and Water Assessment Tool (SWAT)

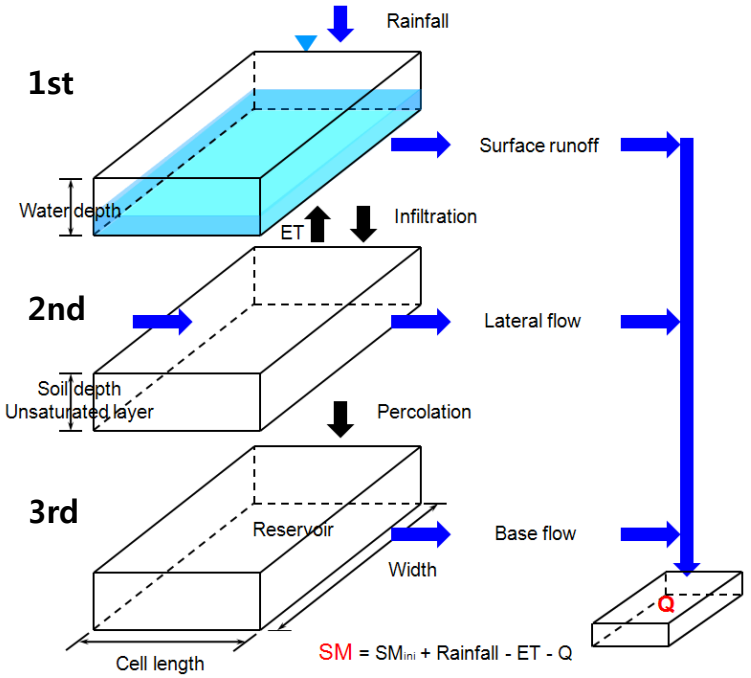
- ✓ SWAT is a physically-based continuous, long-term, semi-distributed-parameter model designed to predict the effects of land management practices regarding the hydrology, sediment and contaminant transport in agricultural watersheds under varying soils, land use and management conditions (Arnold et al., 1998).

- ✓ SWAT subdivides a watershed into sub-basin connected by a stream network, and further delineates HRUs (Hydrologic Response Unit) consisting of unique combinations of land cover and soils within each sub-basin.

- ✓ SWAT2005 model version under ArcSWAT 2.0 interface was used in this study.

Grid-based Model

- ✓ 3 layers
- ✓ one layer for surface runoff
- ✓ two layers for subsurface and base flow
- ✓ 2nd layer: soil moisture routing
- ✓ Runoff : Soil Conservation Service (SCS) method
- ✓ Surface Runoff

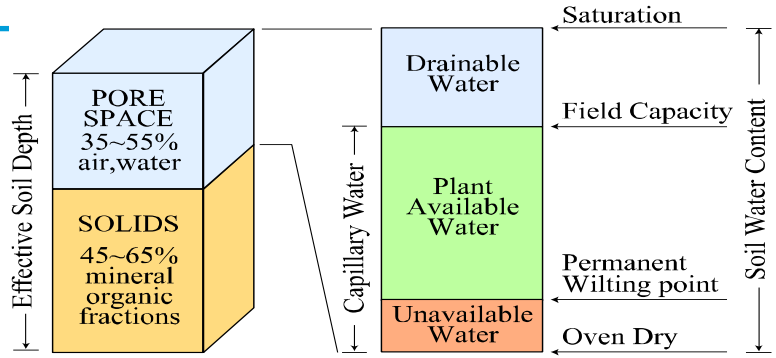


$$Q'_{surf} = \frac{(P - 0.2S^2)}{P + 0.8S}, P \geq 0.2S \quad S = PO_e - SM_{t-1}$$

- ✓ Subsurface flow

$$Q_{latf} = K_{sat} \cdot S_o, FC < SM < PO_e$$

$$Q_{latf} = 0, SM < FC$$



Grid-based Model

- ✓ Soil Water Balance

$$SM_t = SM_{t-1} + P - ET - Q_{surf} - Q_{latf} - Q_{basf}$$

- ✓ Evapotranspiration : Penman-Monteith

$$\lambda ET = \frac{\Delta(R_n - G) + \rho_a c_p \dfrac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \dfrac{r_s}{r_a}\right)}$$

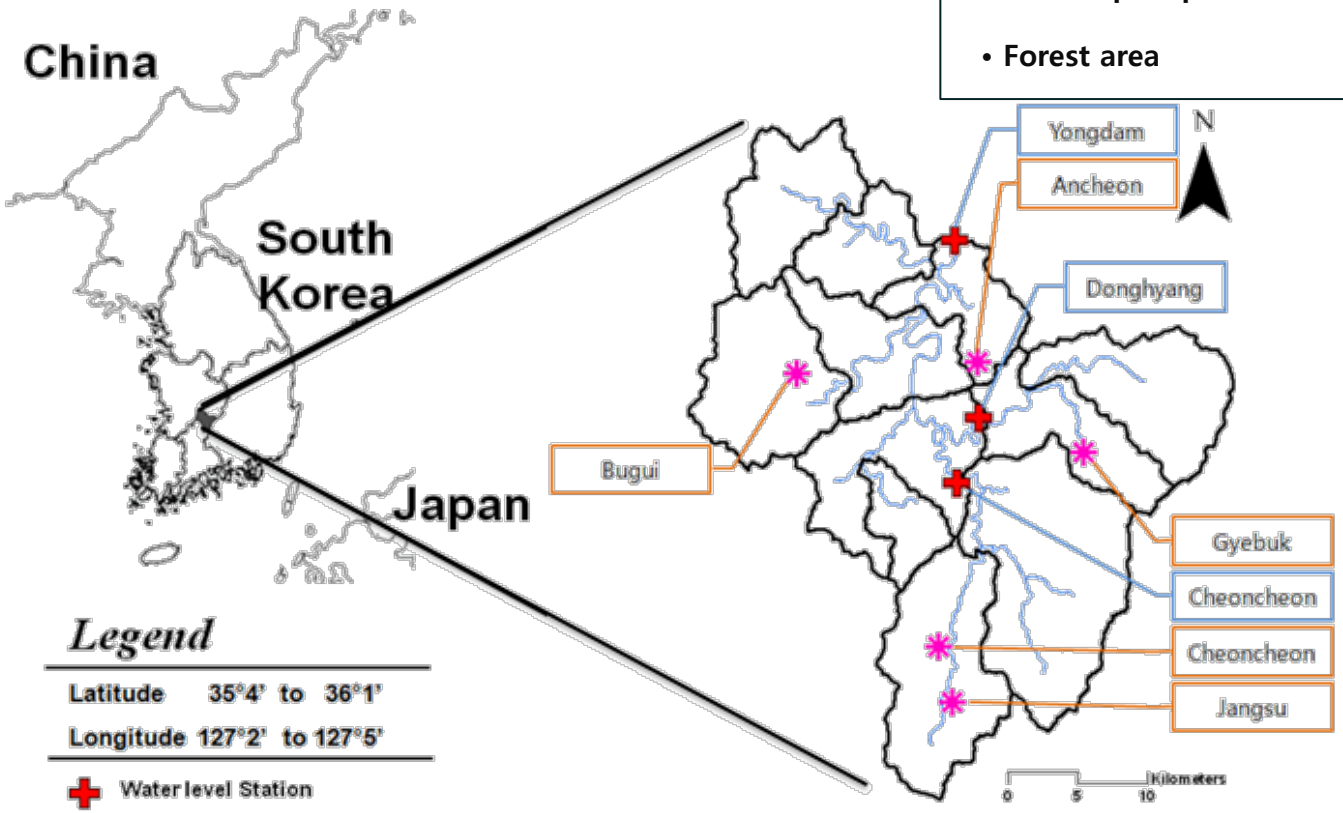
- ✓ LAI (Leaf Area Index, from Terra MODIS Product, MOD15)

$$r_s = \frac{r_1}{LAI_{active}}$$

- ✓ Parameters: surlag(Surface runoff lag coefficient), infilt_rt(Soil infiltration ratio, %), per_rt(Soil percolation ratio,%), slp_l(Lateral flow curve slope, mm/day), time_l(Lateral flow basin lag time, day), slp_b, time_b, ini_soil, length_str etc.

Study Area

- Area : 930 km²
- Water level station : 3
- Weather station : 5
- Soil moisture station : 5
- Annual precipitation : 1,259.7 mm
- Forest area : 70.7 %

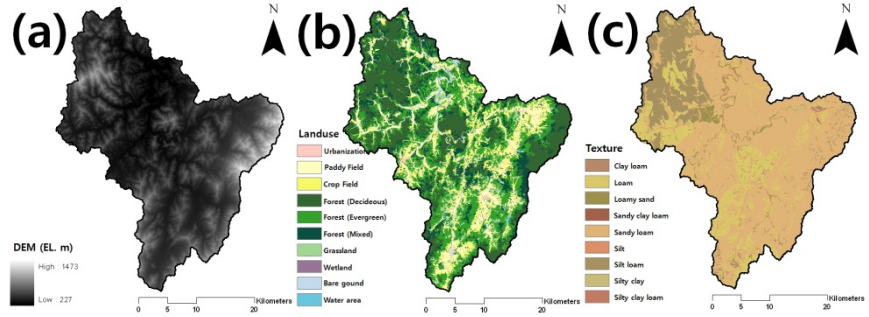


Data

Data		SWAT Model	Grid-based Model
Weather Data	Precipitation (mm)	Daily Data / Text Data (dbf File) (2001 ~ 2009)	Daily Data / Grid Data (ASC File) (2001 ~ 2009)
	Temperature (℃)		
	Sunshine hour (hour) / Solar Radiation (MJ/d)		
	Wind speed (m/s)		
	Relative humidity (%)		
Observed Data	Streamflow (mm)		
	Soil moisture (%)		

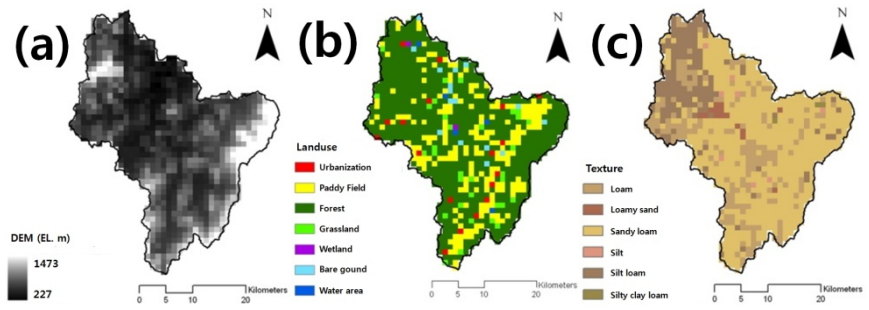
30m

SWAT Model



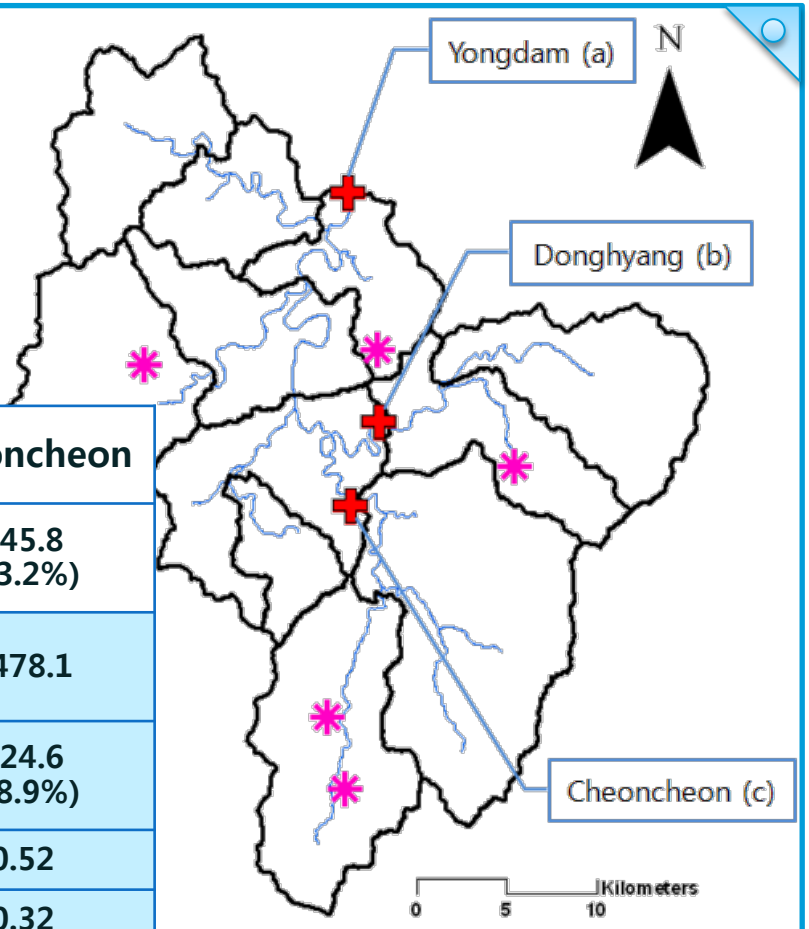
1000m (col: 46, row: 55)

Grid-based Model



Streamflow

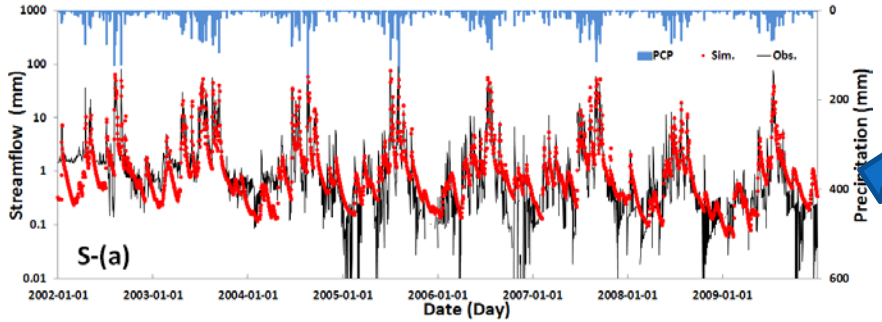
Station		Yongdam	Donghyang	Cheoncheon
Streamflow	Obs. (mm)	878.8 (59.4%)	845. 7 (57.8%)	945.8 (73.2%)
SWAT	PCP (mm)	1401.3	1401.3	1478.1
	Sim. (mm)	878.8 (60.3%)	747.9 (50.6%)	824.6 (58.9%)
	R^2	0.46	0.71	0.52
	NSE	0.34	0.55	0.32
Grid-based	PCP (mm)	1478.7	1291.6	1462.6
	Sim. (mm)	906.9 (61.3%)	880.0 (60.2%)	740.7 (57.3%)
	R^2	0.85	0.79	0.76
	NSE	0.82	0.63	0.61

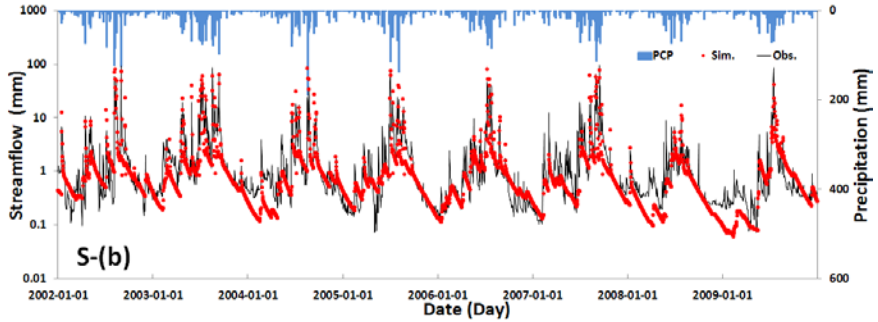


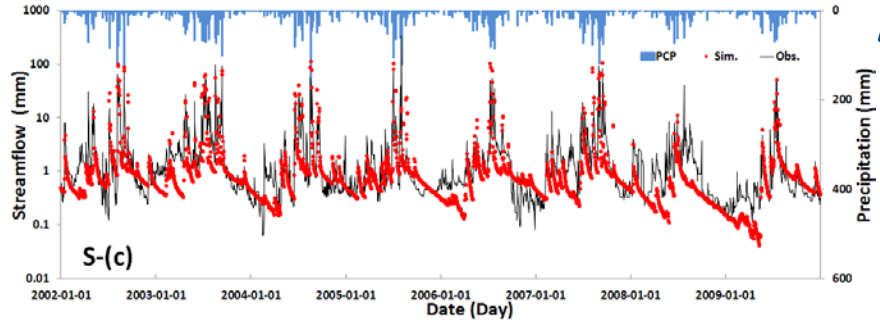
Streamflow

PCP • Sim. —Obs.

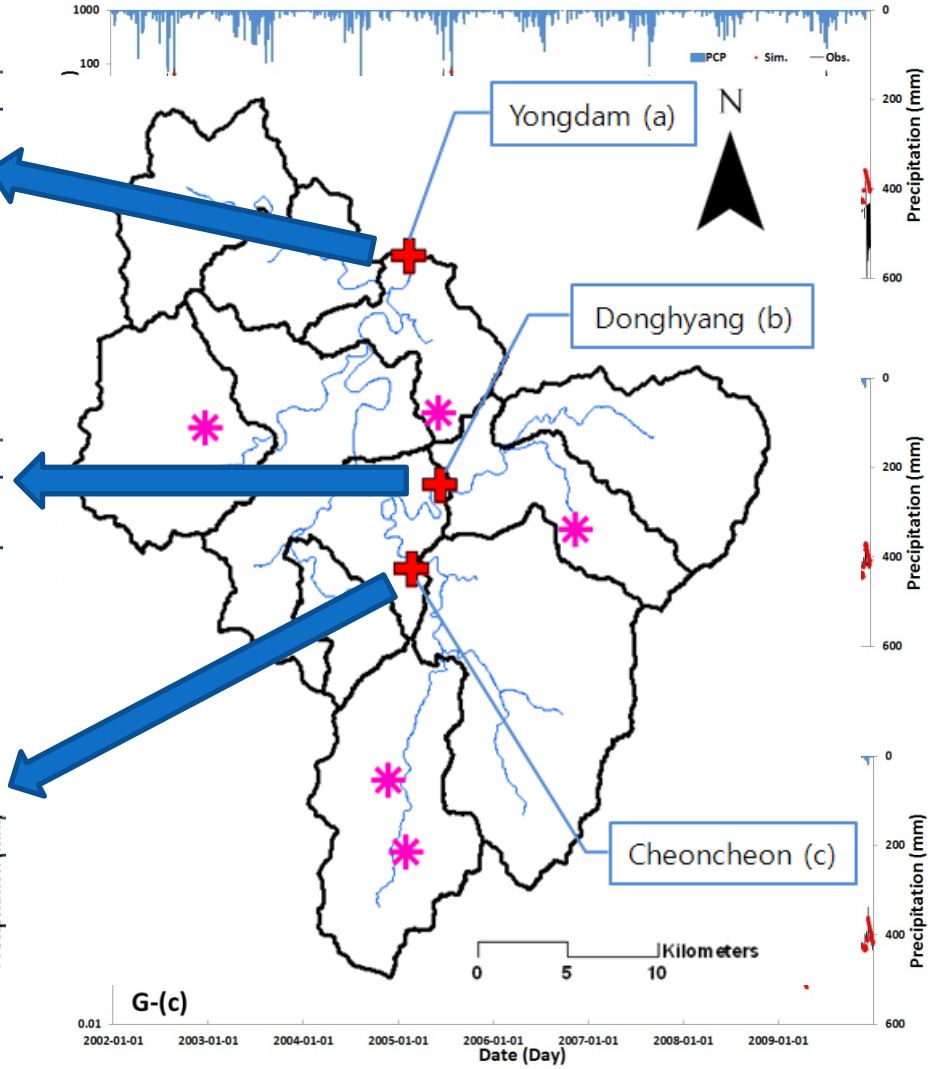
SWAT Model







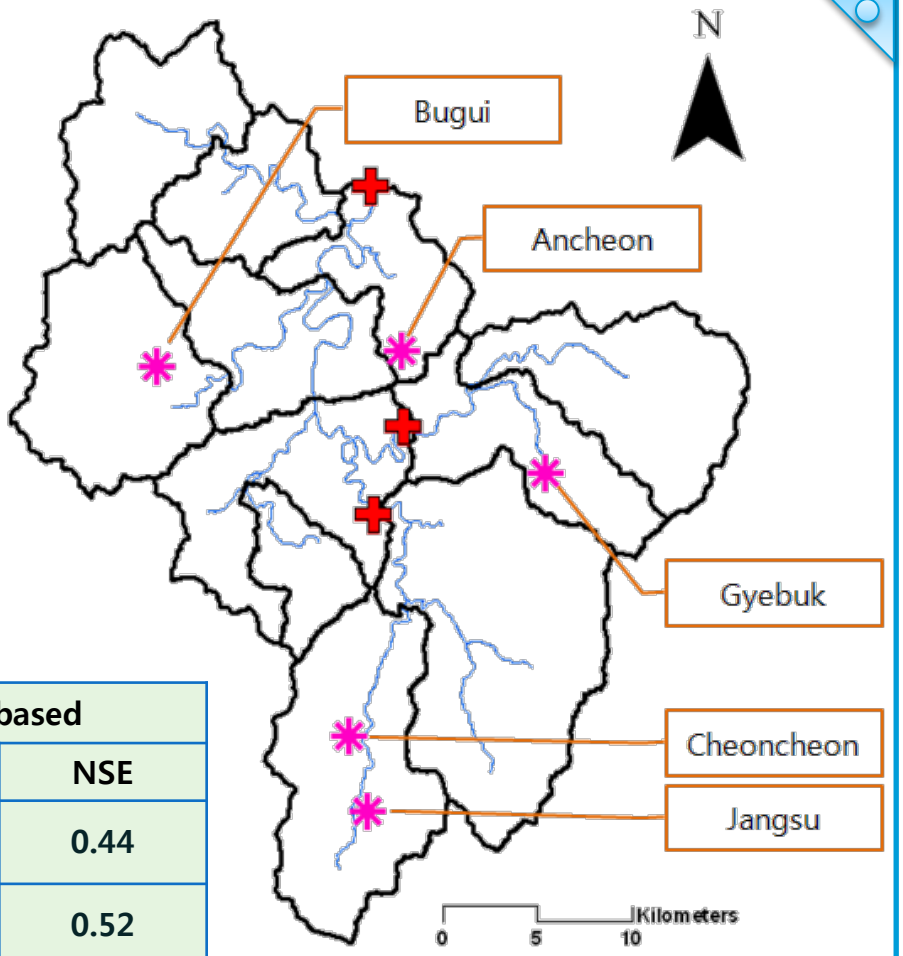
Grid-based Model



Soil Moisture

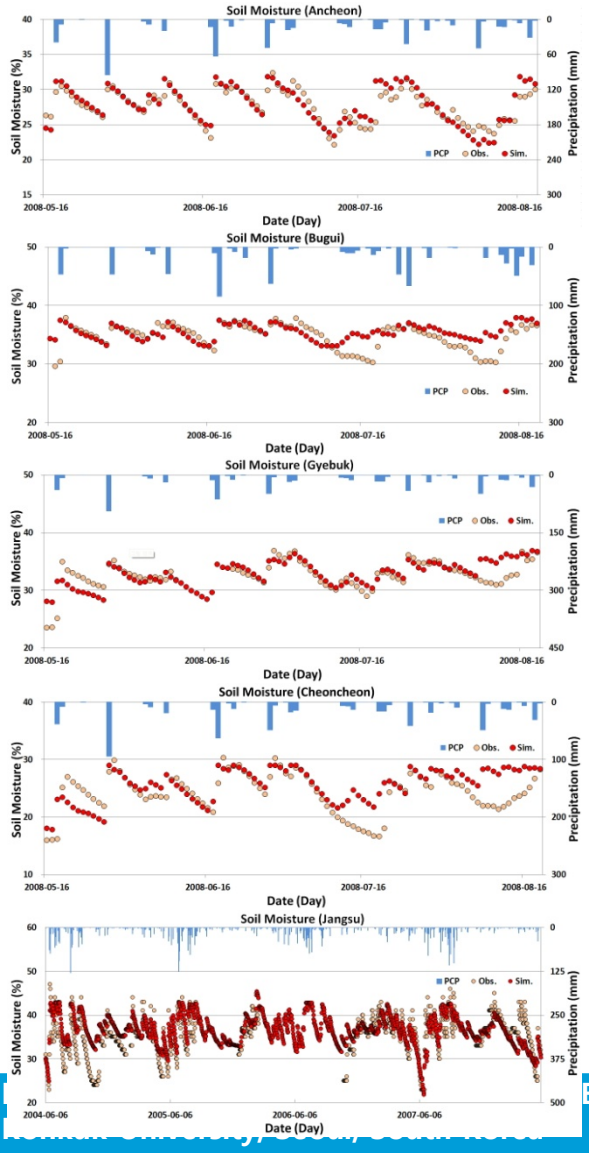
Soil moisture Station	Soil Type	Land use
Jangsu	Sandy Loam	Evergreen
Ancheon	Sandy Loam	Mixed Forest
Cheoncheon	Loam	Evergreen
Gyebuk	Sandy Loam	Evergreen
Bugui	Silt Loam	Evergreen

Soil moisture Station	SWAT		Grid-based	
	R^2	NSE	R^2	NSE
Jangsu	0.49	0.42	**0.36**	**0.44**
Ancheon	0.76	0.65	**0.86**	**0.52**
Cheoncheon	0.40	0.20	**0.47**	**0.18**
Gyebuk	0.47	0.47	**0.67**	**0.38**
Bugui	0.27	0.15	**0.59**	**0.58**

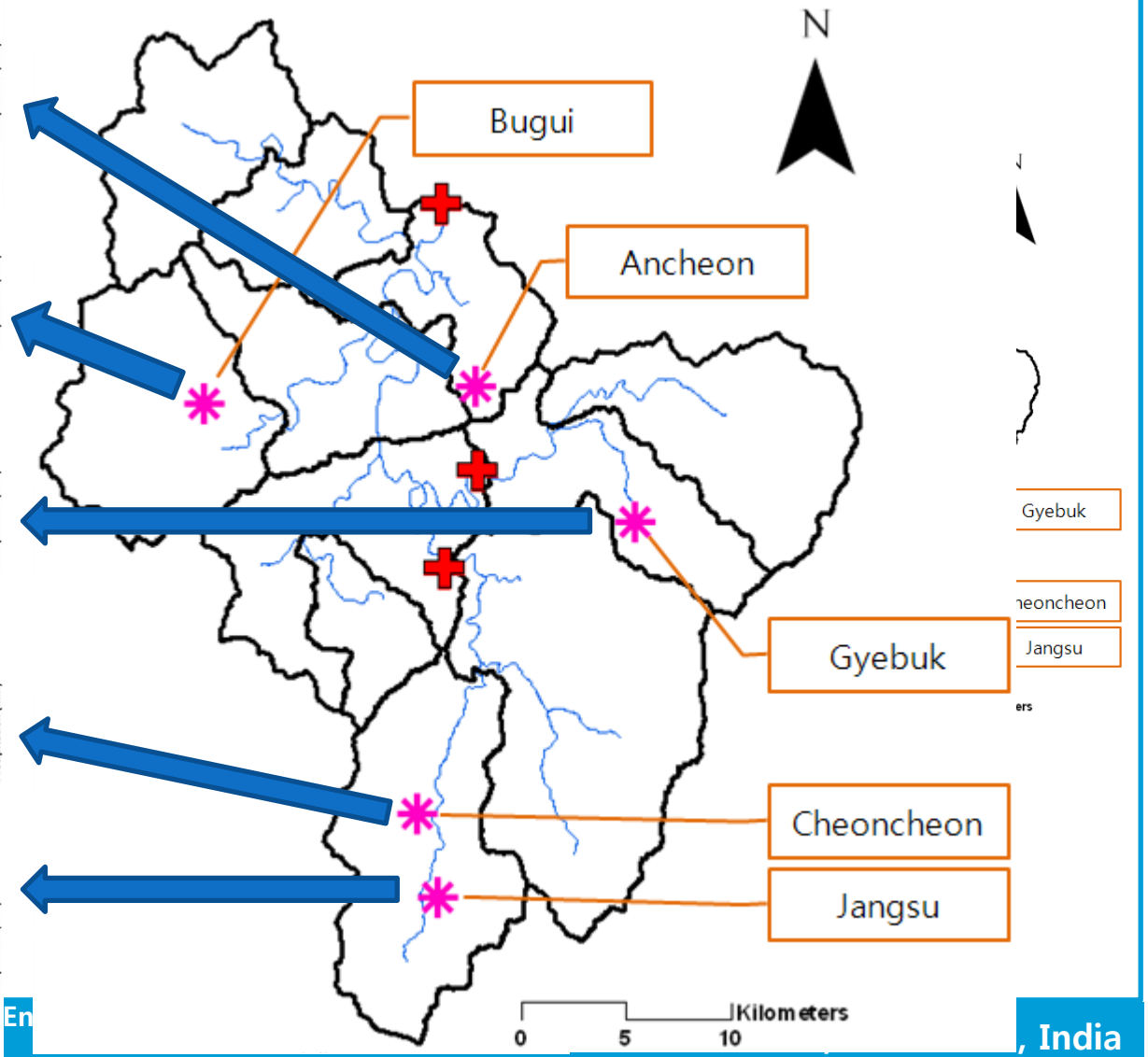


Soil Moisture

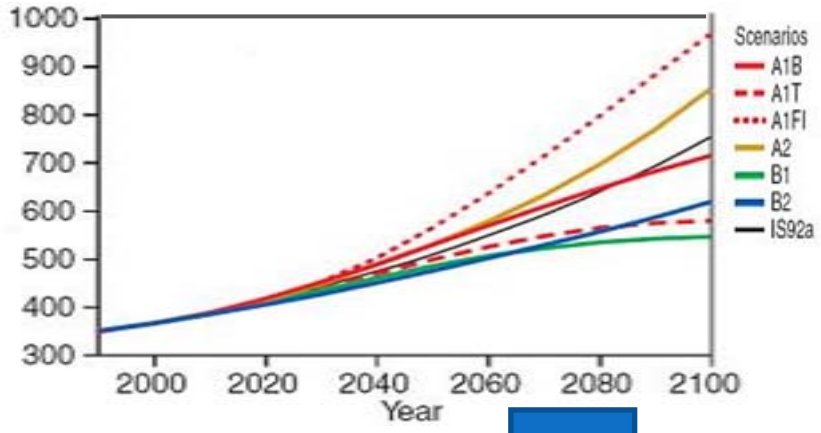
SWAT Model



Grid-based Model



SRES Scenario AR4 (Special Report on Emission Scenario)



Society-Economy Scenario

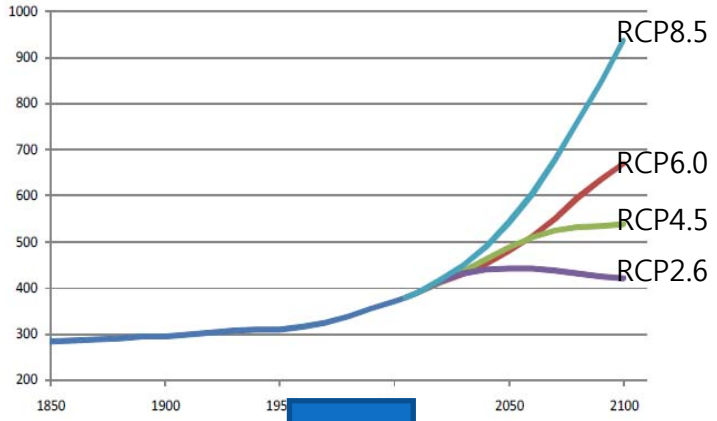
Emission Scenario

Radiative Forcing

Climate Change Scenario

Effect, Adaptation, Vulnerability Research

RCP Scenario AR5 (Representative Concentration Pathway)



Radiative Forcing (RCP)

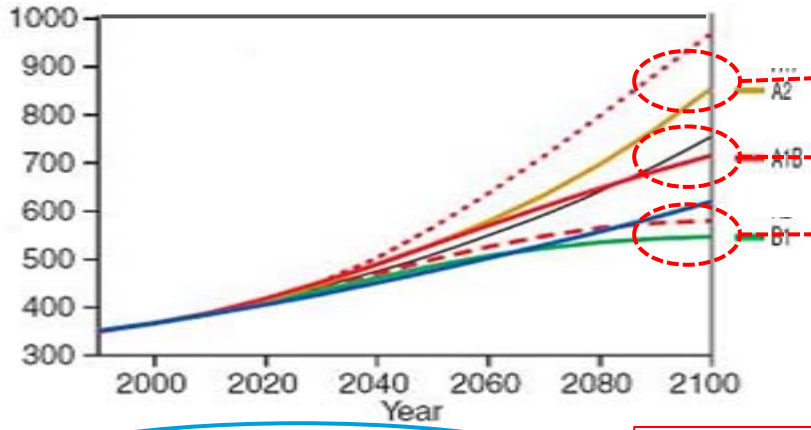
Climate Change Scenario

Society-Economy, Emission Scenario

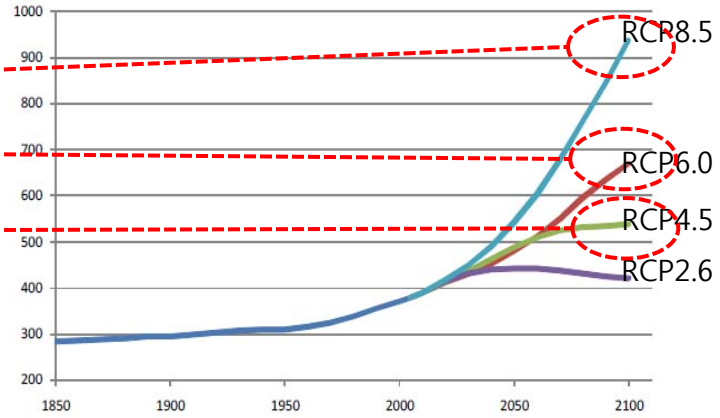
Scenario Combine

Effect, Adaptation, Vulnerability Research

SRES Scenario AR4 (Special Report on Emission Scenario)



RCP Scenario AR5 (Representative Concentration Pathway)



Future Social Structure

2100 year Concentration

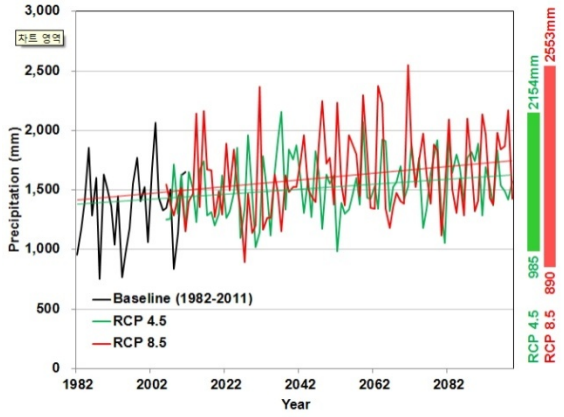
Liaison with Climate Change Response Policy

Diversity Society	A2	830
High Developing Society	A1B	720
Sustainable Developing Society	B1	550

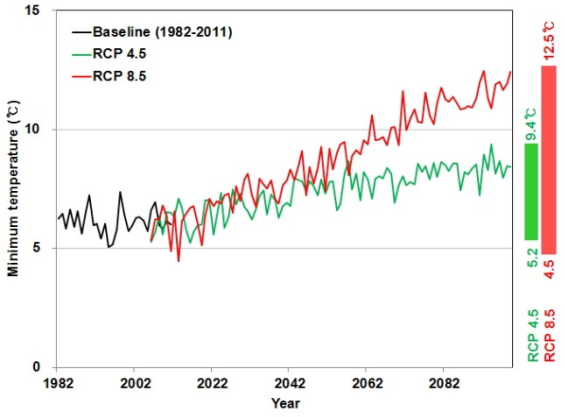
940	RCP8.5	Emission as Present
670	RCP6.0	Moderate Reduction Policy
540	RCP4.5	Considerable Reduction Policy
420	RCP2.0	Self Recovery Function

Bias Correction

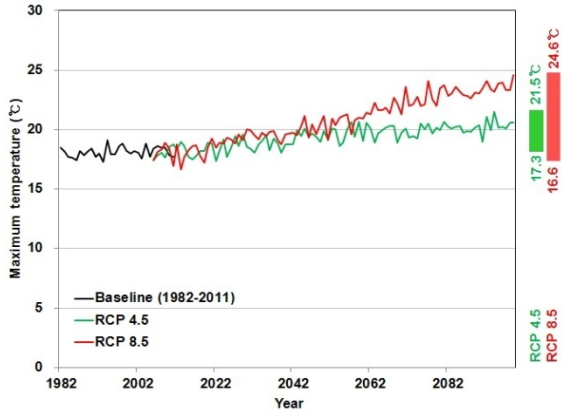
Precipitation



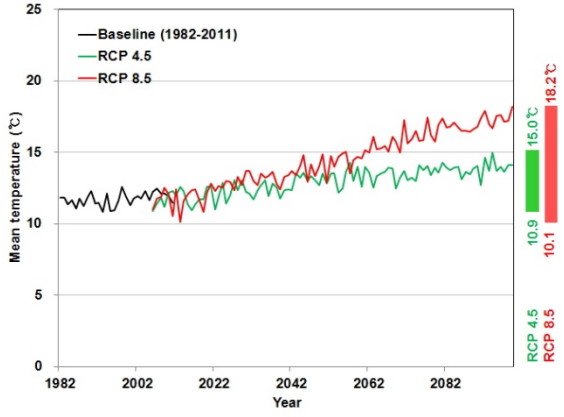
Minimum Temperature



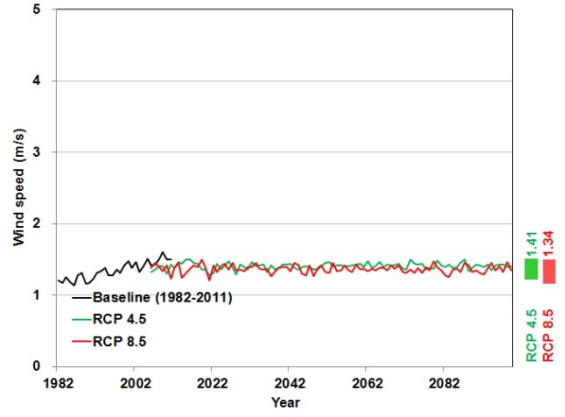
Maximum Temperature



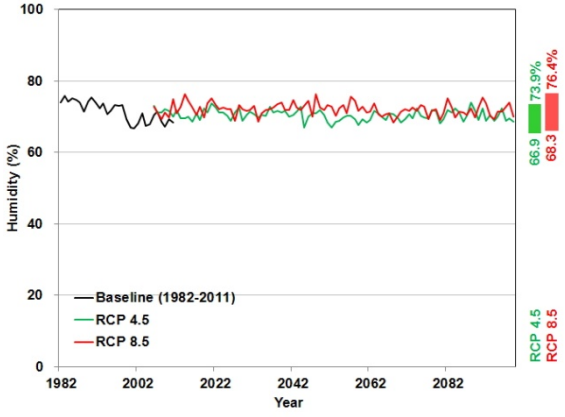
Mean Temperature



Wind Speed

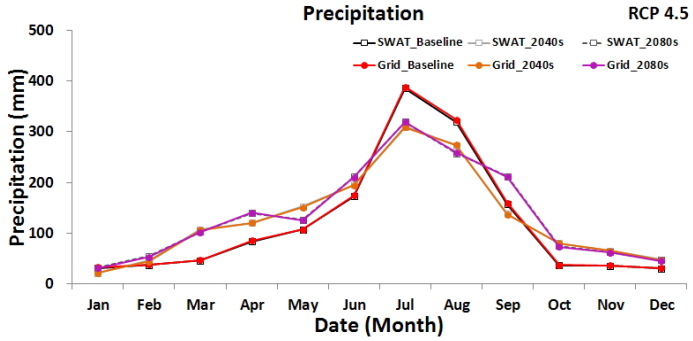


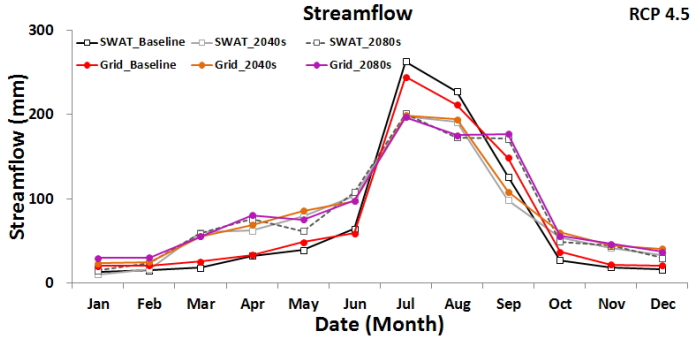
Humidity

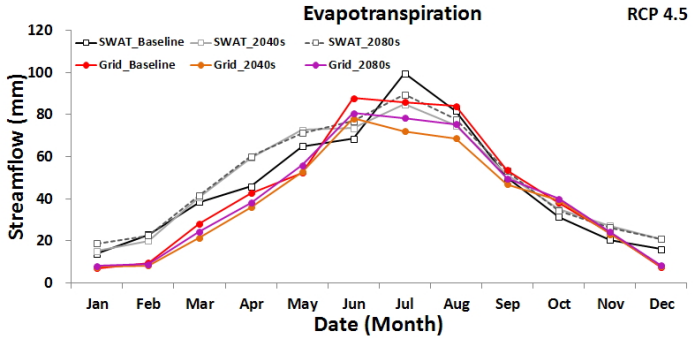


Application

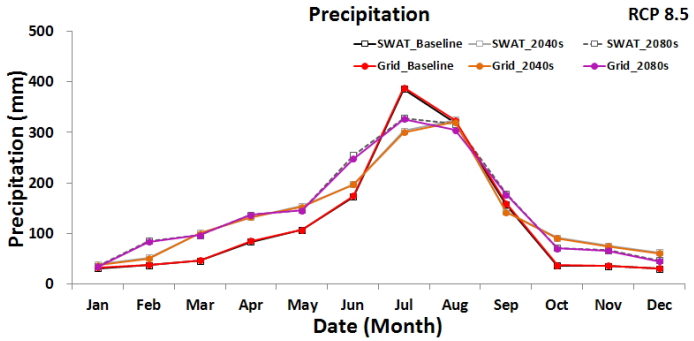
RCP 4.5

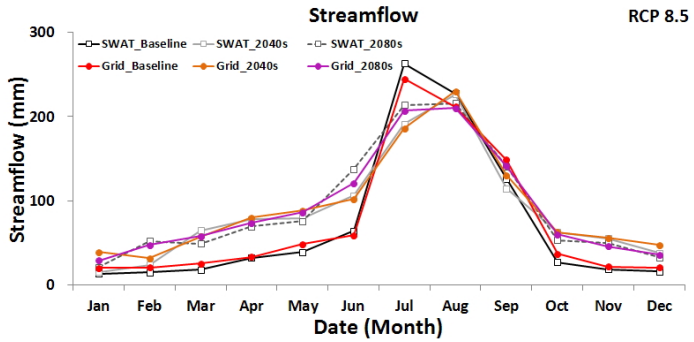


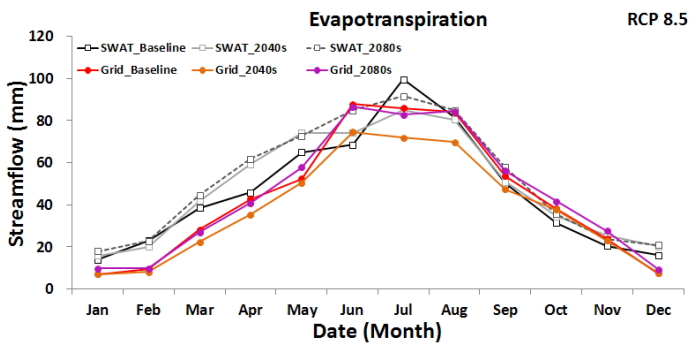




RCP 8.5



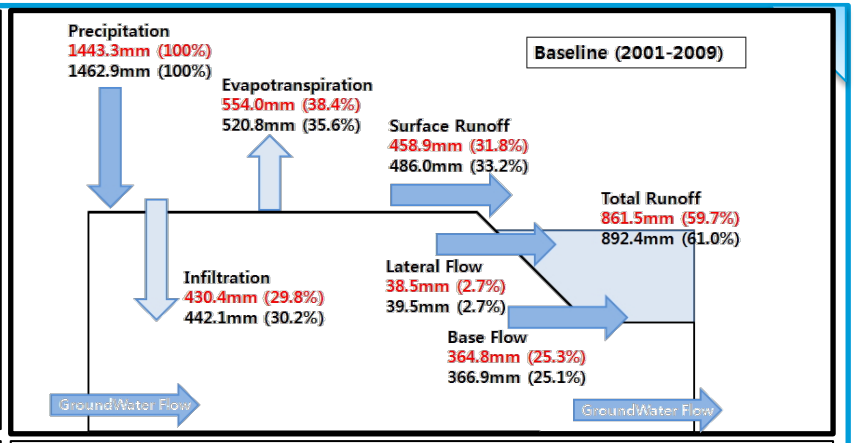




Water Balance

SWAT Model
Grid-based Model

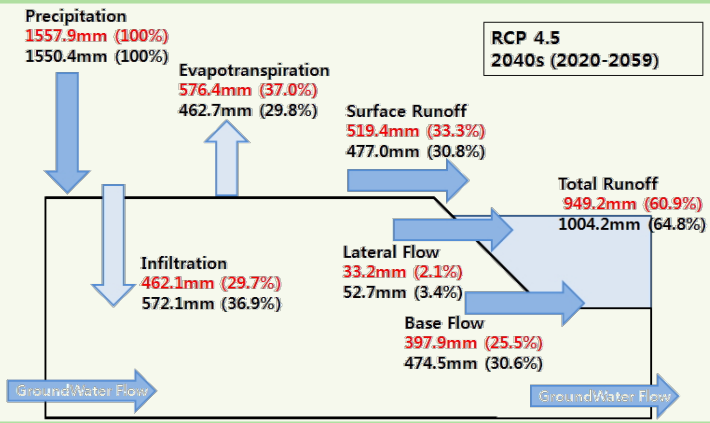
Baseline

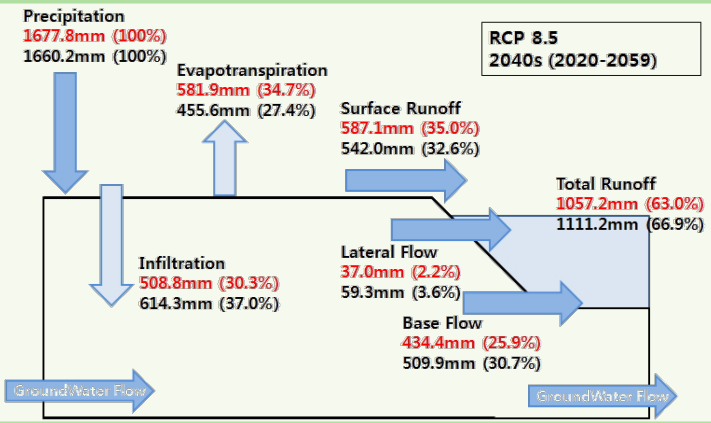


RCP 4.5

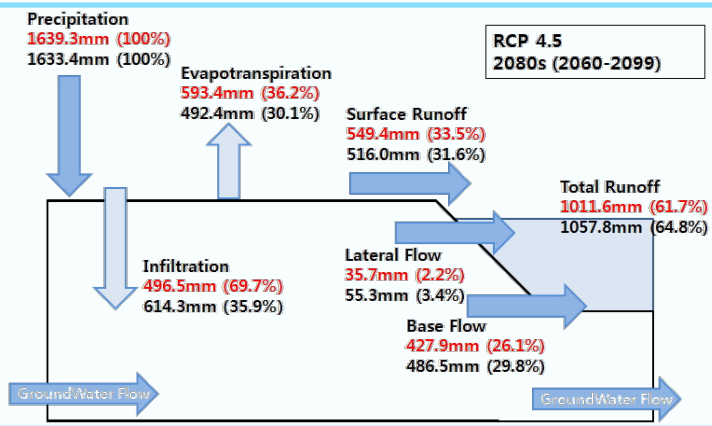
RCP 8.5

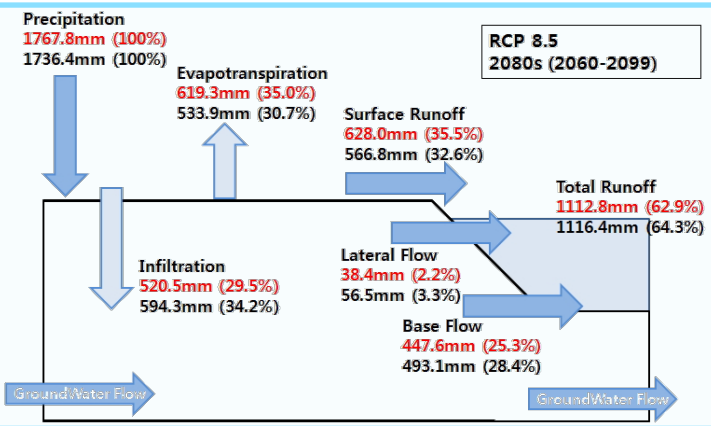
2040s





2080s

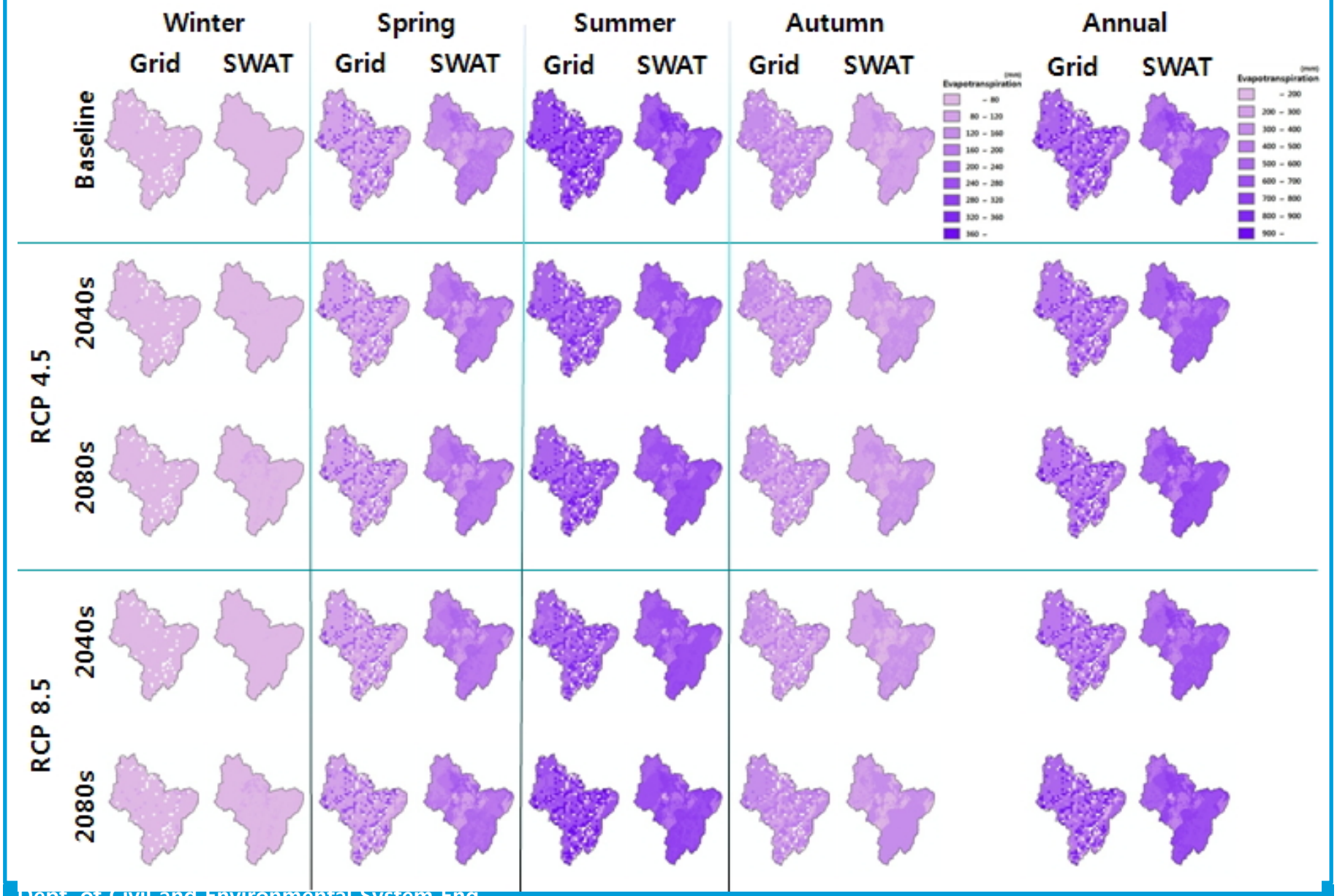




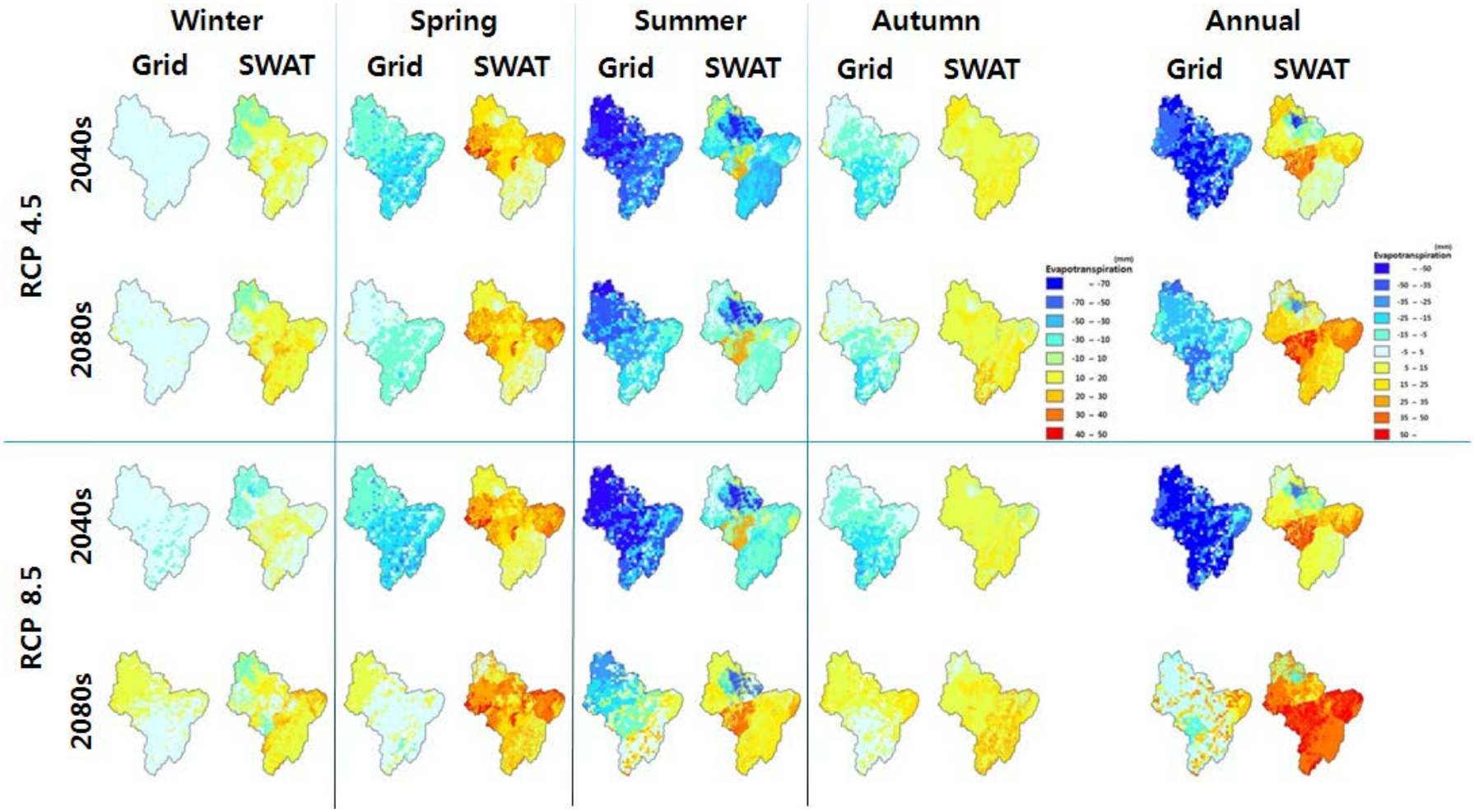
( ) : percent of change based on baseline

	SWAT Model					Grid-based Model				
	Baseline (2001-2009)	RCP 4.5		RCP 8.5		Baseline (2001-2009)	RCP 4.5		RCP 8.5	
		2040s	2080s	2040s	2080s		2040s	2080s	2040s	2080s
PCP (mm)	1443.3	1557.9 (+7.9)	1639.3 (+13.6)	1677.8 (+16.2)	1767.8 (+22.5)	1462.9	1550.4 (+6.0)	1633.4 (+11.7)	1660.2 (+13.5)	1736.4 (+18.7)
ET (mm)	554.0	576.4 (+4.0)	593.4 (+7.1)	581.9 (+5.0)	619.3 (+11.8)	520.8	462.7 (-11.2)	492.4 (-5.5)	455.6 (-12.5)	533.9 (+2.5)
Q_{surf} (mm)	458.9	519.4 (+13.2)	549.4 (+19.7)	587.1 (+27.9)	628.0 (+36.8)	486.0	477.0 (-1.9)	516.0 (+6.2)	542.0 (+11.5)	566.8 (+16.6)
Q_{lat} (mm)	38.5	33.2 (-13.8)	35.7 (-7.3)	37.0 (-3.8)	38.4 (-0.1)	39.5	52.7 (+33.4)	55.3 (+40.2)	59.3 (+50.3)	56.5 (+43.0)
Q_{sub} (mm)	364.8	397.9 (+9.1)	427.9 (+17.3)	434.4 (+19.1)	447.6 (+22.7)	366.9	474.5 (+29.3)	486.5 (+32.6)	509.9 (+39.0)	493.1 (+34.4)
Q_{tot} (mm)	861.5	949.2 (+10.2)	1011.6 (+17.4)	1057.2 (+22.7)	1112.8 (+29.2)	892.4	1004.2 (+12.5)	1057.8 (+18.5)	1111.2 (+24.5)	1116.4 (+25.1)

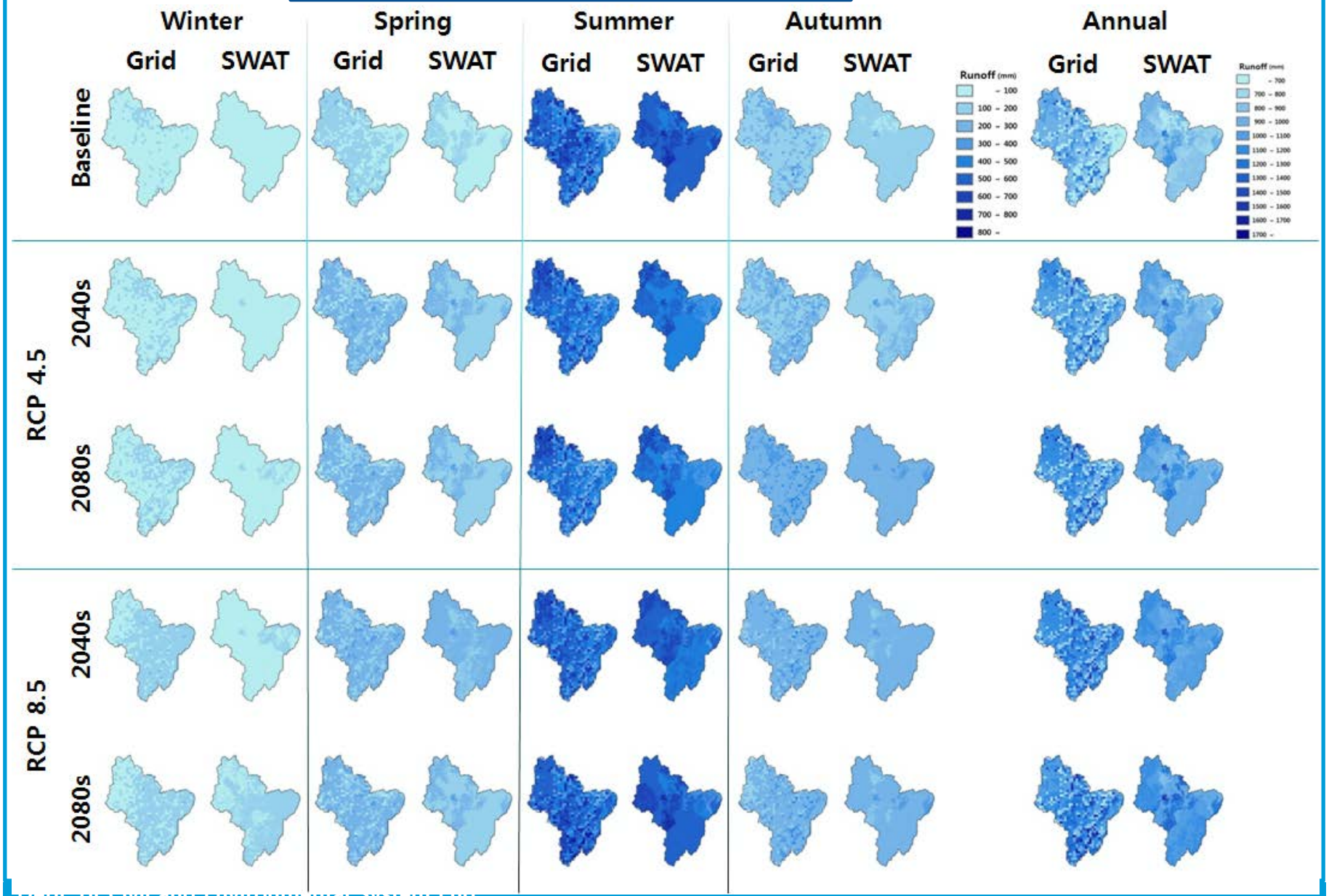
Evapotranspiration (Distribution Map)



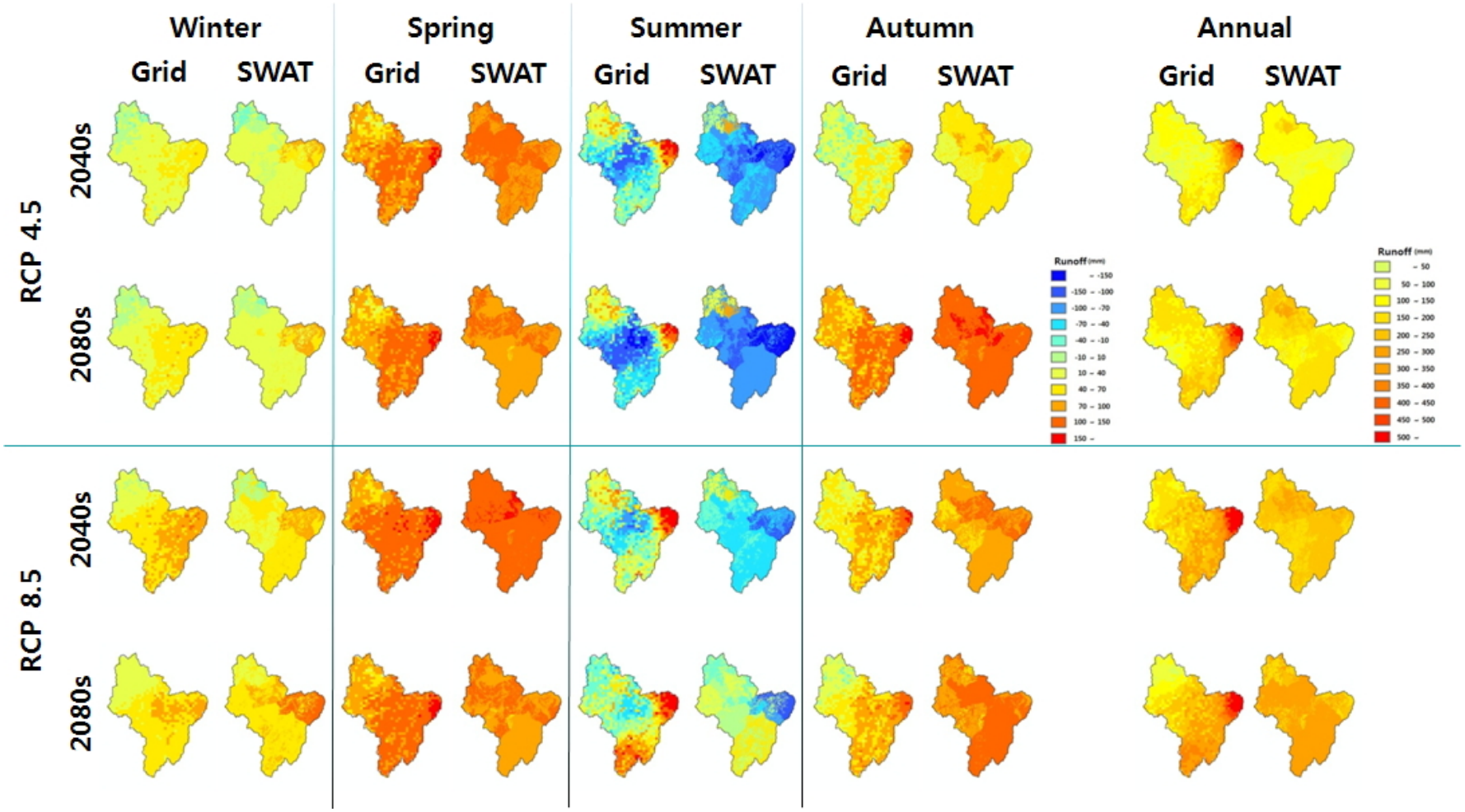
Evapotranspiration (Difference Map)



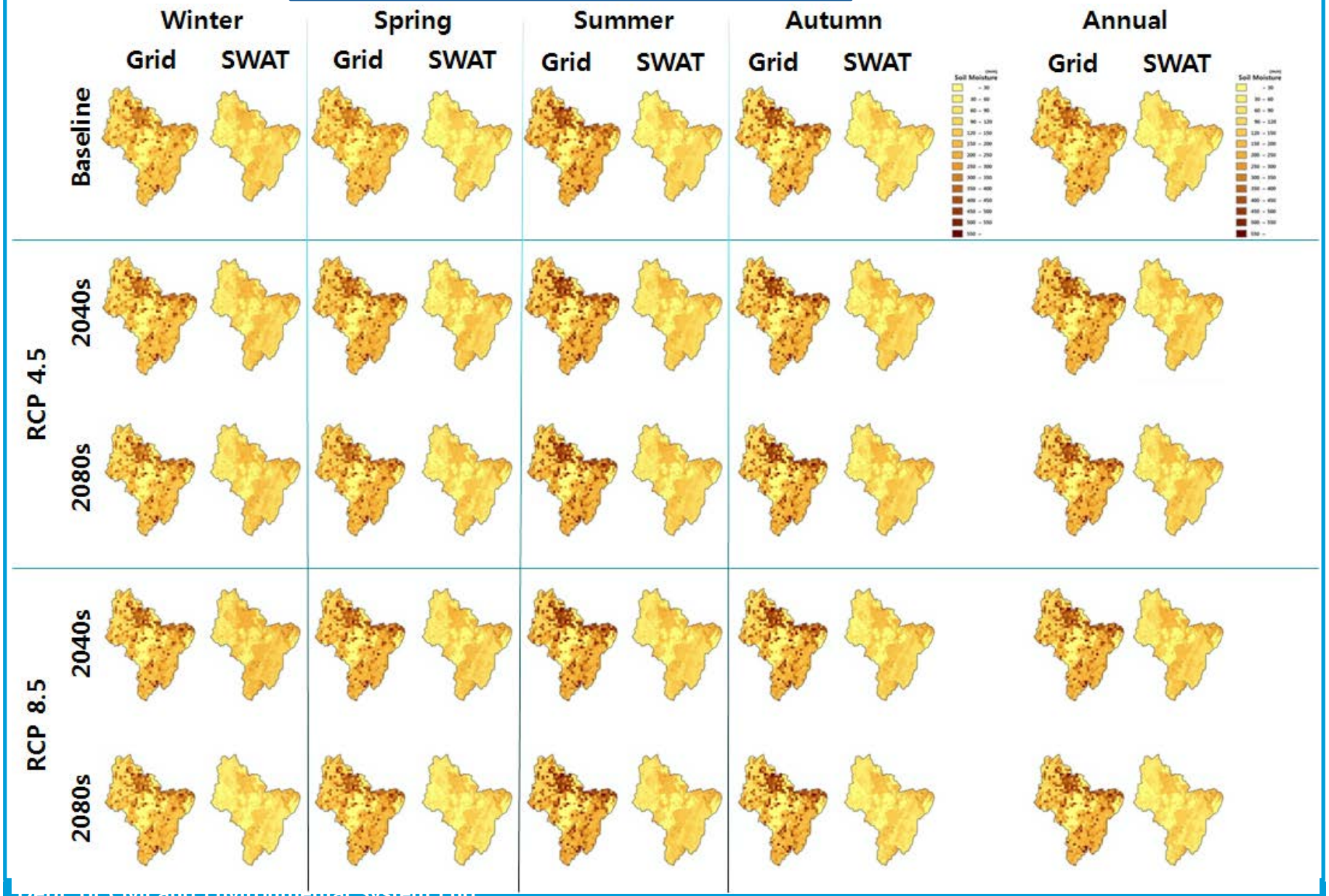
Runoff (Distribution Map)



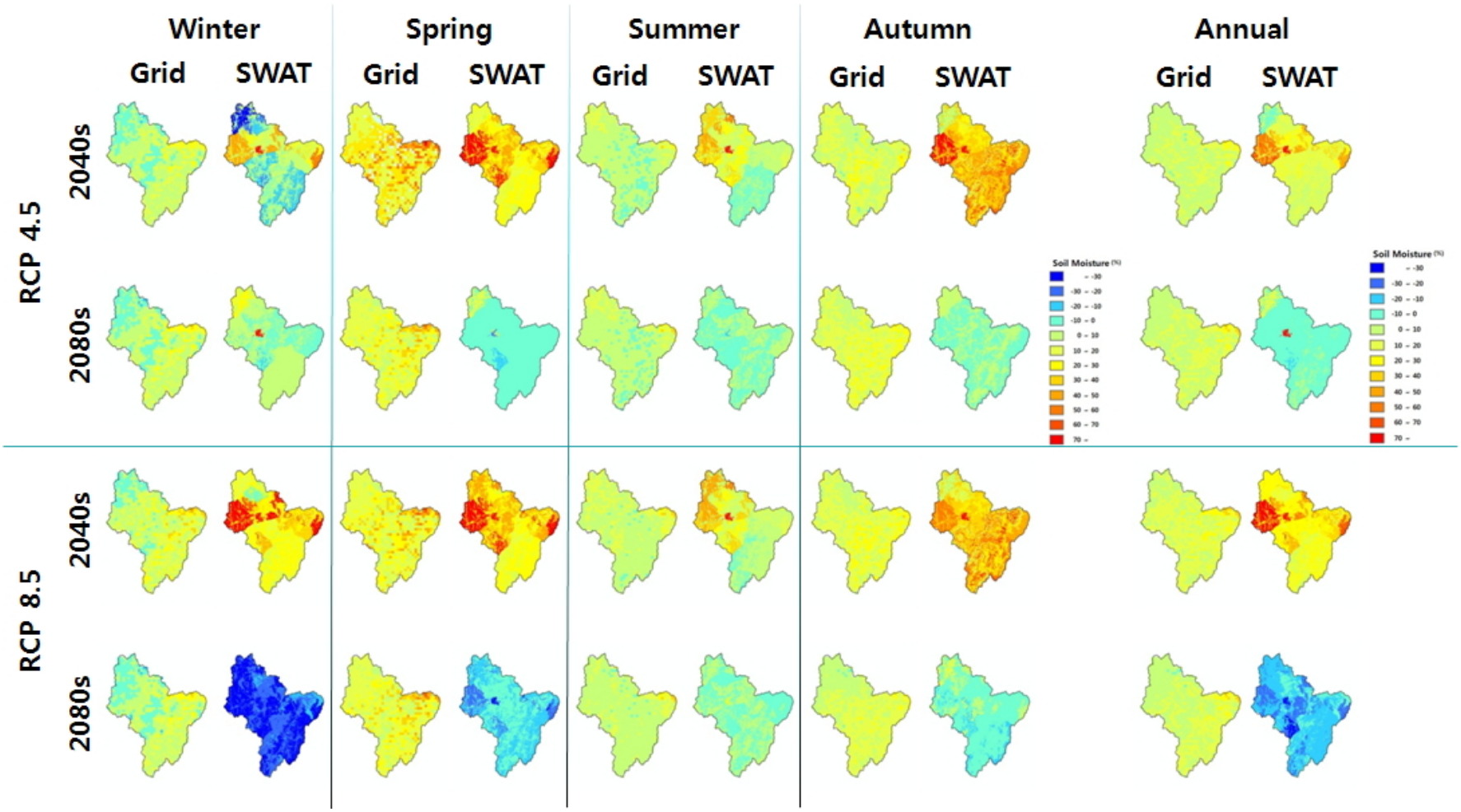
Runoff (Difference Map)



Soil Moisture (Distibution Map)



Soil Moisture (Difference Map)



Concluding Remarks

- We introduced a grid-based continuous hydrological model. They will be applied to project the future South Korea watershed hydrology by applying climate change scenarios.

- We need more modeling efforts for the underestimated ET and soil moisture routing.

- The model hopes to be called as **PGA-CC** (**P**rojection of hydrology via **G**rid-based **A**ssessment for **C**limate **C**hange), and will be developed as a software at the end of this year (Climate Change Assessment & Projection for Hydrology in Korea).

Q&A

For further information, contact:

Jung, Hyuk
Graduate student,
Dept. of Civil & Environmental System Engineering,
Konkuk University
shatiya@konkuk.ac.kr

Thank you

Lap Homepage : http://konkuk.ac.kr/~kimsj/
(Earth Information Engineering Laboratory)

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