

# **H08 Manual**

# **User's Edition**

## **Supplement 2: Regional Application**

### **- Case Study of the Korean Peninsula**

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## Version information

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# Chapter 1

## Introduction

Understand what is described in this manual, and what is not.

### General introduction

This manual explains how to setup H08 for a specific geographical domain. To make explanation concrete, it takes the Korean Peninsula as an example of the study domain (see the cover figure of this manual).

If you follow the instructions in this manual, you will be successfully setup the H08 model for any study domain at any spatial resolution. Please note that to avoid overlaps with the global manual (“H08 Manual User’s Edition”, Hanasaki and Yamamoto, 2010), this manual basically includes only the procedures of running H08 without detailed explanations of rules, theories, and backgrounds. Readers are strongly recommended to complete the global manual beforehand. Additionally, the authors recommend the readers to exactly follow this manual without modifying anything for the first time. H08 is carefully designed to provide maximum freedom to the experts. Saying in different way, H08 offers minimum usability to the beginners. Even tiny errors in settings may stop or collapse the simulations. First, please make sure that all of the procedures shown in this manual are reproduced on your system. Then, please change the settings one by one toward your research objective.

### Installation

If you have completed the global manual or completed H08 global runs, you can skip this part.

1. Set adm/Mkinclude file
2. Change working directory to  $\{\text{DIRH08}\}$  and execute `install.sh` to install H08.

## Chapter 2

### Preparing Map Data

Following the procedures, you will prepare geographical map data for H08 simulation in Korea.

#### 2.1 Creating H08 basic spatial information

1. Change directory to `${DIRH08}/map/pre` and execute `prep_basemap.sh` with the default (global) setting. This results in creating the base maps of global domain.
2. Execute `prep_basemap.sh` with the revised (regional) setting (see below). This results in creating the base map of a regional domain (i.e. Korea in this case). For example, `map/dat/grd_ara_/grdara.ko5` must look like Figure 1.

Seven parameters shown below determine the study domain of H08. The setting that were used in this manual is shown below. `L` is a number of total grid cells ( $84 \times 132 = 11088$  in this case). `XY` are numbers of horizontal and vertical grid cells. `LONLAT` consists of four real numbers indicating the longitude of western and eastern edge and the latitude of southern and northern edge (E124, E131, N33, N44 respectively in this case). `L2X` and `L2Y` are the files to set coordinate and generated when `prep_basemap.sh` is executed. `SUF` is the suffix of the input/output file. You can set any name, but it must start with a dot (.) and in total 4 characters (.ko5 stands for Korea at a spatial resolution of 5 arc-minutes). `MAP` is a label to identify the base map used (SNU is short for the Seoul National University who prepared the base map). Hereafter, this manual refers these settings as “the Regional Settings”. Please do not change anything else unless specifically instructed.

```
L=11088
XY="84 132"
LONLAT="124 131 33 44"
L2X=../../map/dat/l2x_l2y_/l2x.ko5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.ko5.txt
SUF=.ko5
MAP=.SNU
```

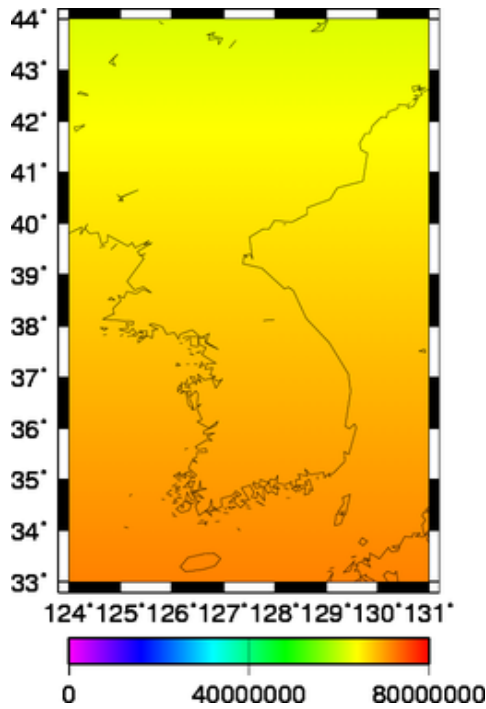


Figure 1. Grid Area (m<sup>2</sup>)

## 2.2 Creating the map data required to use the land surface module

1. Download map-org-GSWP2.tar.gz from the H08 File Server. Decompress map-org-GSWP2.tar.gz in `${DIRH08}/map/org`.
2. Change working directory to `${DIRH08}/map/pre` and execute `prep_lnd_GSWP2.sh` with the default setting. This results in creating the global land mask and land area files.
3. Check whether `${DIRH08}/map/dat/flw_dir_` exists in your system. If not, make a new empty directory.
4. Download map-org-KOR.tar.gz from the H08 File Server. Decompress map-org-KOR.tar.gz in `${DIRH08}/map/org`.
5. Download and decompress map-pre-KOR.tar.gz in `${DIRH08}/map/pre`. You will find a new shell script named `prep_KOR.sh`
6. Make sure that you are working at `${DIRH08}/map/pre`. Execute `prep_KOR.sh`. This results in creating the flow direction and land mask file of the study domain.

Now the following two files are located in your system.

`map/dat/lnd_msk_/lndmsk.SNU.ko5` (Figure 2)

`map/dat/flw_dir_/flwdir.SNU.ko5` (Figure 3)

7. Execute the command below. This results in creating the land area file (Figure 4).

```
%
maskko5 ../../map/dat/grd_ara_/grdara.ko5 ../../map/dat/lnd_m
sk_/lndmsk.SNU.ko5 eq 1 ../../map/dat/lnd_ara_/lndara.SNU.ko5
```

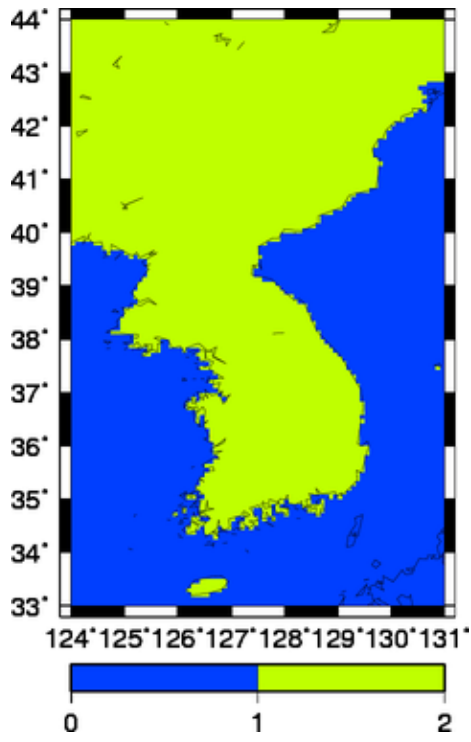


Figure 2. Land mask

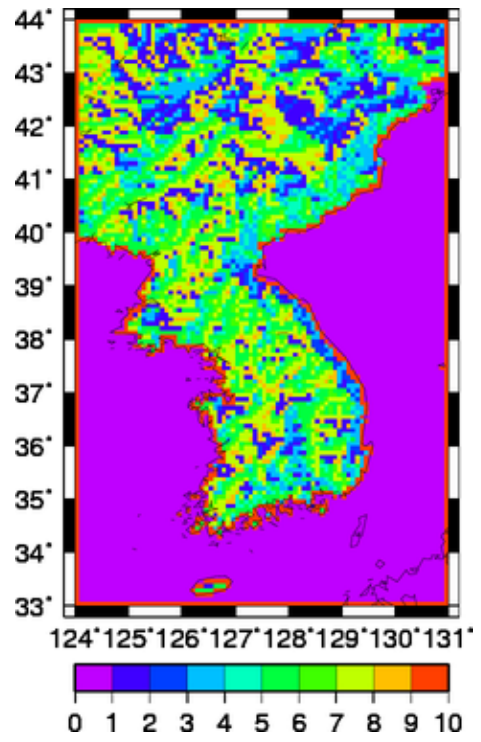


Figure 3. Flow direction

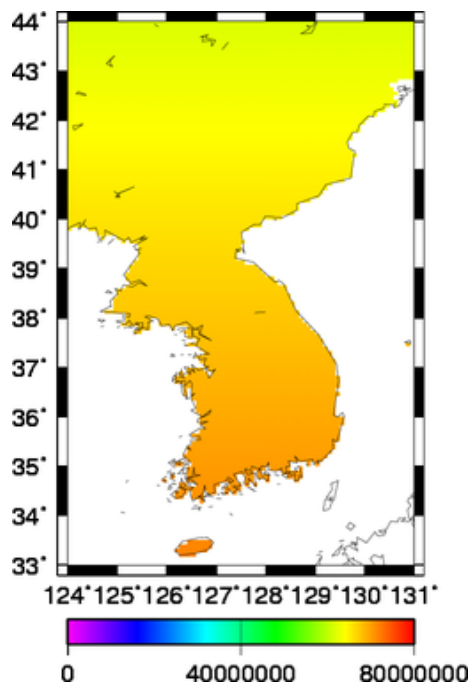


Figure 4. Land area (m<sup>2</sup>)

## 2.3 Creating the map data required to use the river module

---

1. Change the working directory to  $\{\text{DIRH08}\}/\text{map}/\text{pre}$  and execute `prep_riv_GSWP2B1.sh` with the default Setting. This results in creating global flow direction file.
2. Change the working directory to  $\{\text{DIRH08}\}/\text{map}/\text{bin}$  and execute `main_riv.sh` with the Regional Setting. This results in creating the files including river flow sequence, L coordinate of next grid, grid distance, catchment area(Figure 5) and catchment number(Figure 6) which are indispensable in the river simulation.

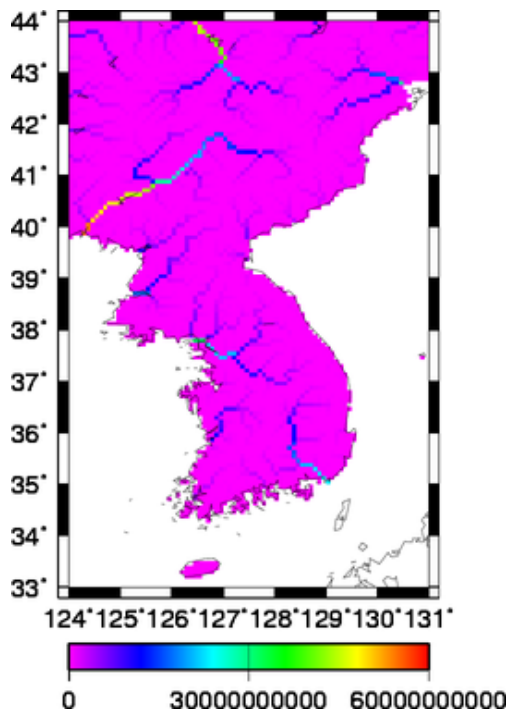


Figure 5. Catchment area (m<sup>2</sup>)

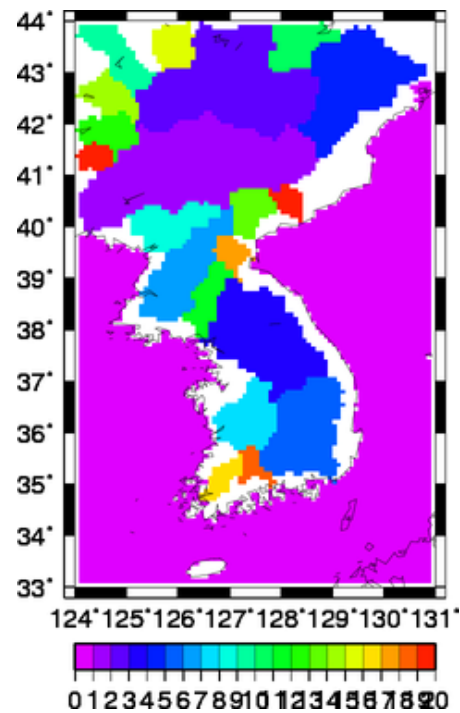


Figure 6. Catchment number (Top 20)

## 2.4 Creating the map data required to use the crop module

---

1. Download and decompress `map-org-C05.tar.gz` and `map-org-AQUASTAT.tar.gz` in `map/org`.
2. Change the working directory to  $\{\text{DIRH08}\}/\text{map}/\text{pre}$ . Execute `prep_map_C05_nat.sh` with the default setting. This results in creating the global national border information.
3. Execute `prep_map_C05_pop.sh` with the default setting. This results in creating the global population data.
4. Make sure that the directory  $\{\text{DIRH08}\}/\text{map}/\text{dat}/\text{nat\_cod\_}$  is in your system. If not, make a new directory, then download and locate `C05_____20000000.txt` there.
5. Download and decompress `map-org-R08.tar.gz`, `map-org-M08.tar.gz`, `map-org-S05.tar.gz`, `map-org-DS02.tar.gz` in `map/org`.
6. Execute `prep_crp_R08M08S05.sh` with the default setting. This results in creating the cropland area, harvested area and irrigated area.
7. Execute `prep_crp_DS02.sh` with the default setting. This results in creating the irrigation area, cropping intensity and irrigation efficiency.

8. Execute `prep_map_AQUASTAT.sh` with changing the parameters `L` and `SUF` as shown below. This results in creating the agricultural, industrial and domestic water withdrawal.

```
L=9331200
SUF=.g15
```

9. Make sure whether `htextract` exists in `${DIRH08}/bin`. `H08_20130501` and earlier versions may not include `htextract`. If this is the case, follow the instruction shown in the “Bugs & Update” page of the H08 website ([http://h08.nies.go.jp/h08/bugs\\_update.html](http://h08.nies.go.jp/h08/bugs_update.html)).
10. Execute `prep_map_region.sh` with the Regional Setting. This results in creating the population, nation mask, agricultural, industrial and domestic withdrawal and demand in Korea.  
(`map/dat/pop_tot/C05_a_20000000.ko5`(Figure 7),  
`map/dat/nat_msk/C05_20000000.ko5`(Figure 8),  
`map/dat/wit_agr/AQUASTAT20000000.ko5`(Figure 9),  
`map/dat/wit_ind/AQUASTAT20000000.ko5`(Figure 10),  
`map/dat/wit_dom/AQUASTAT20000000.ko5`(Figure 11),  
`map/dat/dem_ind/AQUASTAT20000000.ko5`(Figure 12),  
`map/dat/dem_dom/AQUASTAT20000000.ko5`(Figure 13))
11. Change directory to `${DIRH08}/map/pre` and execute `prep_crp_region.sh` with the Regional Setting. This results in creating the crop information in Korea.  
(`map/dat/crp_int/DS02_00000000.ko5`, `map/dat/irg_eff/DS02_00000000.ko5`,  
`map/dat/irg_ara/S05_20000000.ko5`(Figure 14),  
`map/dat/crp_ara/R08_20000000.ko5`(Figure 15))
12. Change directory to `${DIRH08}/map/bin` and execute `calc_crptyp.sh` with the Regional Setting. This results in creating the crop type data (i.e. crop species or cultivar) of the first and second crop.  
(`map/out/crp_typ1/M08_20000000.ko5`, `map/out/crp_typ2/M08_20000000.ko5`)
13. Execute `${DIRH08}/map/bin/calc_crpfrc.sh` with the Regional Setting. This results in creating the areal fraction of four land use types, namely, double crop irrigated cropland, single crop irrigated cropland, rainfed cropland and other land use.  
(`map/out/crp_int1/DS02_0000.ko5`, `map/out/crp_int2/DS02_0000.ko5`,  
`map/out/irg_arad/S05_20000000.ko5`, `map/out/irg_aras/S05_20000000.ko5`,  
`map/out/rfd_ara/S05_20000000.ko5`, `map/out/non_ara/S05_20000000.ko5`,  
`map/out/irg_frcd/S05_20000000.ko5`, `map/out/irg_frcs/S05_20000000.ko5`,  
`map/out/rfd_frc/S05_20000000.ko5`, `map/out/non_frc/S05_20000000.ko5`)

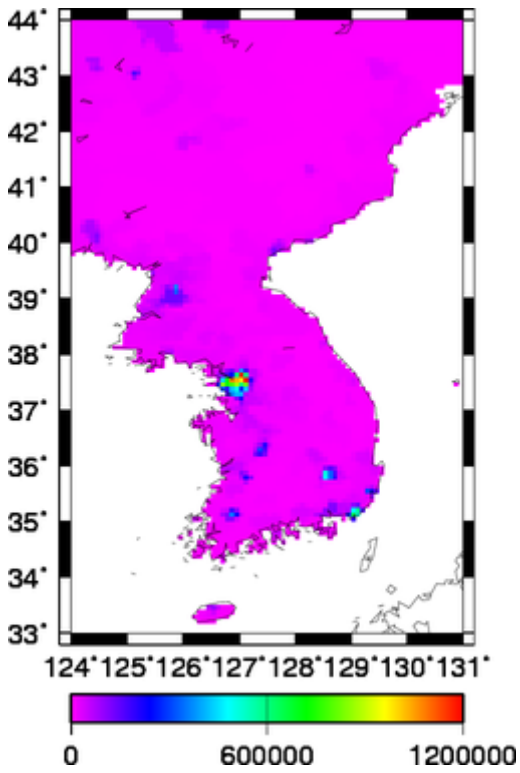


Figure 7. Population

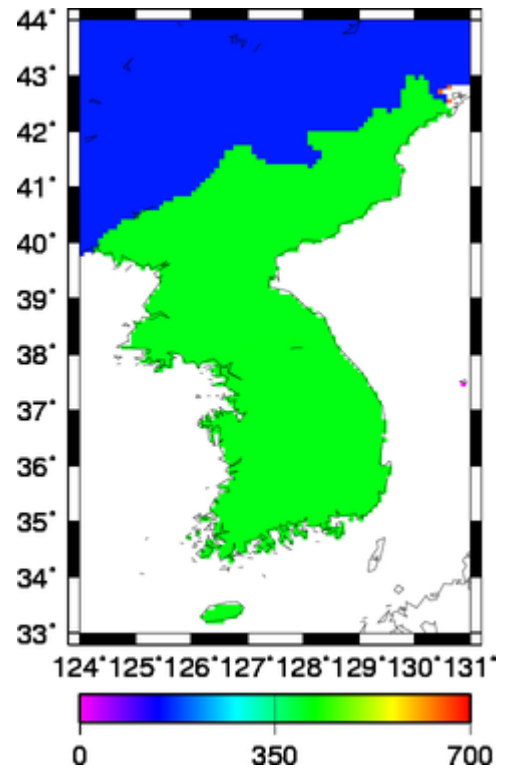


Figure 8. Nation mask

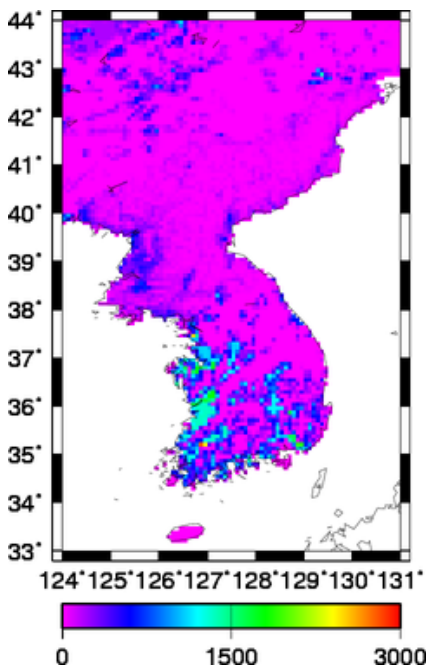


Fig 9. Agricultural water withdrawal

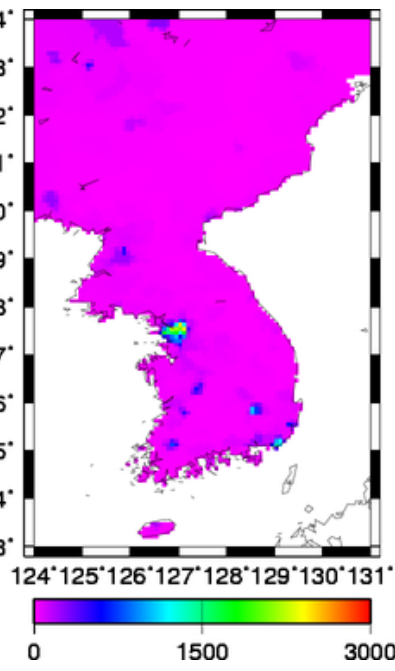


Fig 10. Industrial water withdrawal

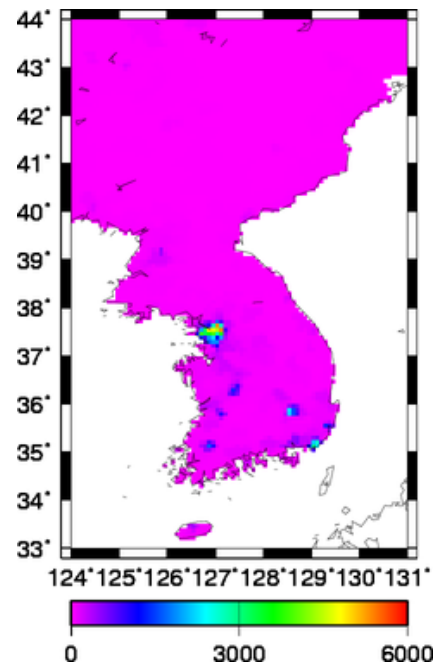


Fig 11. Domestic water withdrawal

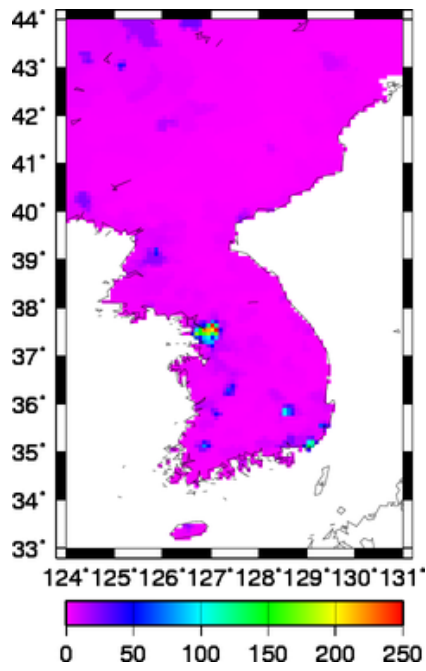


Figure 12. Industrial water demand

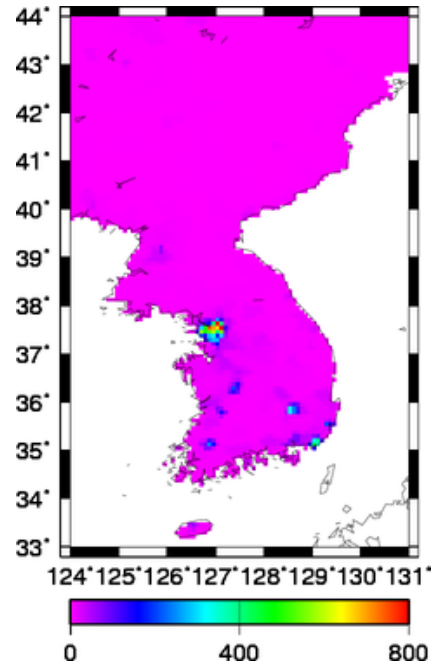


Figure 13. Domestic water demand

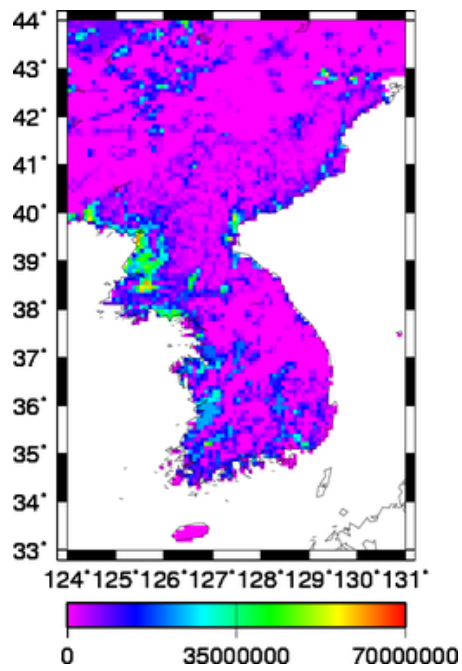


Figure 14. Irrigation area

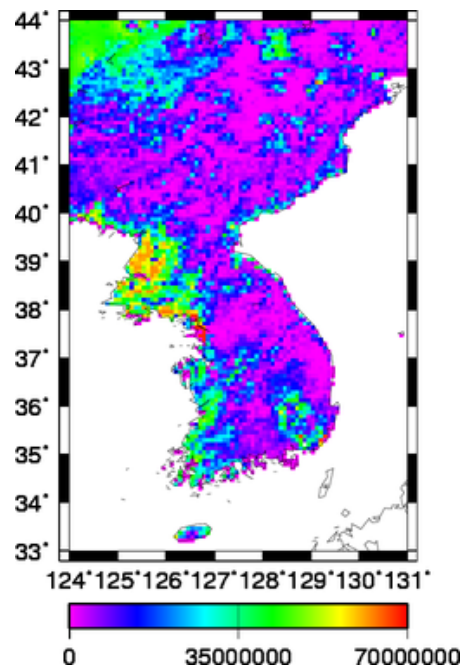


Figure 15. Cropping area

## 2.5 Creating the map data required to use the reservoir module

---

1. Download and decompress map-org-SNU.tar.gz in `${DIRH08}/map/org`.
2. Change directory to `${DIRH08}/map/pre`. Execute `prep_dam_H06.sh` with the Regional Setting. This results in converting the dam list file into H08 2D format.

Calculate average river discharge (Section 6.1) first, then proceed to 3.

3. Change directory to `${DIRH08}/map/bin`. Execute `main_dam.sh` with the Regional Setting. Additionally, change the parameter for DAMDBG as shown below. This results in creating some files including auxiliary information on dams.

```
(map/out/dam_d2s_/H06____00002184.ko5~2194.ko5,  
map/out/dam_d2d_/H06____00002184.ko5~2194.ko5, map/out/dam_up_/H06____.ko5,  
map/out/dam_upc_/H06____.ko5,  
map/out/dam_alc_/GSW2LR__00002184.ko5~2194.ko5,  
map/out/dam_dom_/GSW2LR__.ko5)
```

```
DAMDBG=2189
```

## 2.6 Preparing meteorological data

---

1. Make sure the directory `${DIRH08}/met/org` exists in your system. If not, make an empty directory.
2. Put the GSWP2B1 global meteorological data into `met/org` (See the global manual for detail).
3. Download and decompress `met-pre-KOR.tar.gz` in `met/pre`.
4. Change directory to `met/pre` and execute `prep_GSWP2B1.sh` with the default setting and the parameters below. This results in converting the global meteorological data to the H08 2D format.

```
YEARMIN=1986  
YERAMAX=1995
```

5. Execute `prep_GSWP2B1_Albedo.sh` with the default setting. This results in converting the global Albedo data to H08 2D format.
6. Execute `prep_iplmet.sh`. This results in interpolating the original global 1 x 1 degree meteorological data into regional 5 x 5min.

```
(met/dat/LWdown_/GSW2B1b_19860000.ko5~19951231.ko5,  
met/dat/PSurf_/GSW2B1b_YYYYMMDD.ko5, met/dat/Prcp_/GSW2B1b_  
YYYYMMDD.ko5, met/dat/Qair_/GSW2B1b_YYYYMMDD.ko5,  
met/dat/Rainf_/GSW2B1b_YYYYMMDD.ko5, met/dat/SWdown_/GSW2B1b_  
YYYYMMDD.ko5, met/dat/Snowf_/GSW2B1b_YYYYMMDD.ko5,  
met/dat/Tair_/GSW2B1b_YYYYMMDD.ko5, met/dat/Wind_/GSW2B1b_  
YYYYMMDD.ko5)
```

7. Execute `prep_iplmet_Albedo.sh`. This results in interpolating the global 1 x 1 degree Albedo data into regional 5 x 5min.(`met/dat/Albedo__/_GSW2____19860100.ko5~19951200.ko5`)
8. Execute `prep_mean.sh` with the regional setting. This calculates the mean values between `${YEARMAX}` and `${YEARMIN}` for each variables.

## Chapter 3

### Land Surface Process Module

Following the procedures, you will be able to simulate the land surface process in Korea.

1. Change directory to  $\{\text{DIRH08}\}/\text{ln}/\text{pre}$  and execute `prep.sh` with the Regional Setting. This results in creating the files including land surface parameters and initial values of state variables.
2. Change directory to  $\{\text{DIRH08}\}/\text{ln}/\text{bin}$ . Open `main.f` with text editor, and modify the setting of `n01` in order to make the number consistent with that of L.

```
parameter      (n01=11088)
```

3. Compile the main program.

```
% make main
```

4. Execute `main.sh` with the Regional Setting. The main program on the land surface process will be started.
5. When the simulation completed, change directory to  $\{\text{DIRH08}\}/\text{cpl}/\text{pst}$ . Execute `list_watbal.sh` with the Regional Setting. This results in creating a summary of water balance of the simulation named  $\{\text{DIRH08}\}/\text{tab}/\text{wat\_bal\_}/\text{GSW2LR\_0000000.yyyy.txt}$ . Check the “Water balance of land” section, and make sure that water balance is closed. For Example, Table 1 shows the imbalance is as small as  $-0.01\text{km}^3 \text{yr}^{-1}$ .

Table 1. The results of water balance of land [ $\text{km}^3 \text{y}^{-1}$ ]

Item		Value
Rainfall	+	381.41
Snowfall	+	35.30
Agricultural water supply	+	NA
Evapotranspiration	-	209.10
Total runoff	-	207.62
$\Delta$ Soil moisture	-	0.00
$\Delta$ Snow water equivalent	-	0.00
Water balance of land surface	-	0.01

## Chapter 4 River Module

In this chapter, you can calculate river discharge and river storage in Korea.

1. Change directory to `${DIRH08}/riv/pre` and execute `prep.sh` with the Regional Setting. This results in creating the files including parameter and initial states.
2. Change directory to `${DIRH08}/riv/bin`. Open `main.f` with text editor and modify the setting of `n0l` in order to make the number consistent with that of `L`.

```
n0l=11088
```

3. Compile the main program.

```
% make main
```

4. Change directory to `${DIRH08}/riv/bin` and execute `main.sh` with the Regional Setting. The main program on the river routing process will be started. This results in creating the river discharge (Figure 16) and river storage (Figure 17) data.
6. When the simulation is completed, change directory to `${DIRH08}/cpl/pst`. Execute `list_watbal.sh` with the Regional Setting. This results in creating `${DIRH08}/tab/wat_bal_/GSW2LR__0000000.yyyy.txt`. Check the “Water balance of river” section, and make sure that water balance is closed. For Example, Table 2 shows the imbalance is as small as  $0.00\text{km}^3 \text{yr}^{-1}$ .

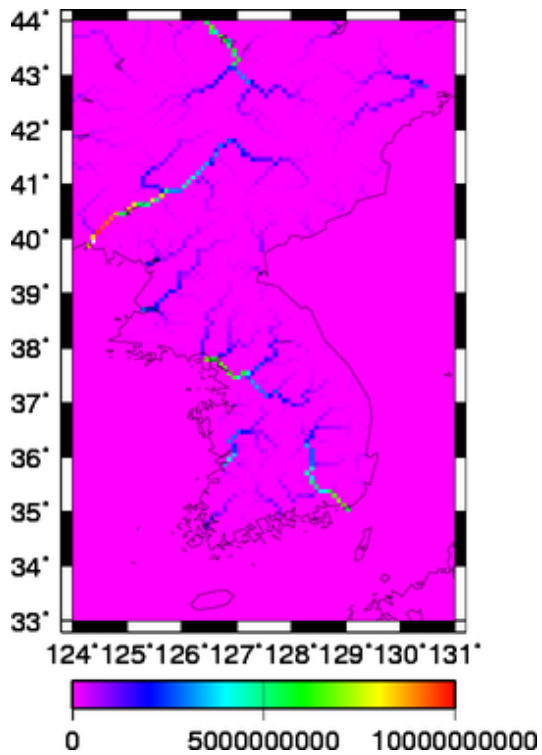


Figure 16. River storage (kg)

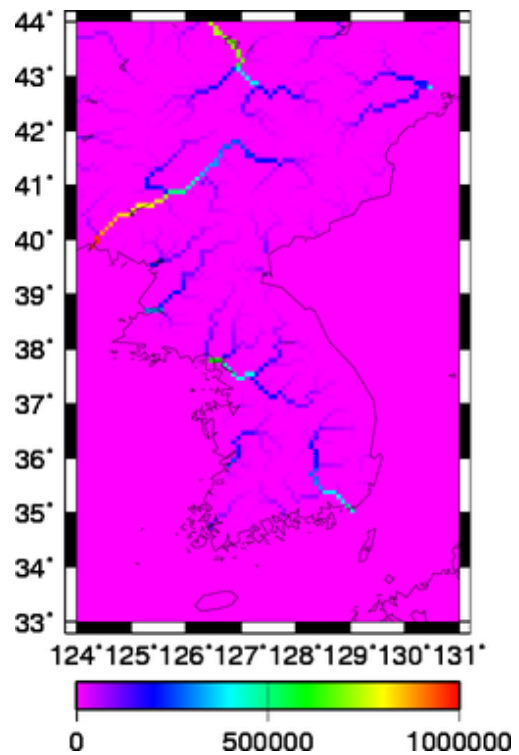


Figure 17. River discharge (kg s<sup>-1</sup>)

Table 2. The results of water balance of river[km<sup>3</sup> y<sup>-1</sup>]

Item	Value
Total runoff	+ 207.62
River discharge	- 207.62
Agricultural water supply	- NA
Industrial water supply	- NA
Domestic water supply	- NA
Agricultural water supply (Medium sized reservoir)	- NA
Industrial water supply (Medium sized reservoir)	- NA
Domestic water supply (Medium sized reservoir)	- NA
Δ River storage	- 0.00
Δ Reservoir storage	- NA
Δ storage	- NA
Water balance of river	0.00

## Chapter 5

### Crop Growth Module

Following the instructions, you will be able to simulate cropping calendar of your study domain.

1. Change directory to `${DIRH08}/crp/pre` and edit `prep.sh`. Since 3 hours files are not prepared, add “#” before “httime” of the line 41 and execute `prep.sh` with the Regional Setting. This results in creating the initial value files (e.g. `${DIRH08}/crp/ini/uniform.0.0.ko5`)
2. Make sure the directory `${DIRH08}/crp/org` exists in your system. If not, make a new empty directory.
3. Download and decompress `crp-org-SWIM.tar.gz` in `${DIRH08}/crp/org`.
4. Change directory to `${DIRH08}/crp/bin` and open `main.f` with text editor and modify the setting of `n0l` in order to make the number consistent with that of `L`.

```
n0lall=84*132
n0llnd=5793
```

You can calculate `n0llnd` by executing the following command.

```
% sumko5 ../../map/dat/lnd_msk_/lndmsk.SNU.ko5
```

5. Compile the main program.

```
% make main
```

6. Execute `main.sh` with the Regional Setting. The main program on the crop growth will be started. This results in simulating the cropping calendars for individual crops.
7. Change directory to `${DIRH08}/crp/pst` and execute `calc_crpcal.sh` with the Regional Setting. This results in determining the cropping calendar of first crop.
8. Change directory to `${DIRH08}/crp/bin` and execute `main.sh` with the Regional Setting. The main program on the crop growth will be started for seeking the possibility of the second crop. This results in creating the cropping calendar of second crop.

```
JOBS=2nd
```

9. Change directory to `${DIRH08}/crp/pst` and execute `draw_crpyld_map.sh` with the Regional Setting. This results in drawing the figures of cropping calendar and estimated maximum potential crop yield in `${DIRH08}/crp/fig`.
10. Look at the figures in `${DIRH08}/crp/fig` and consider whether the results are feasible. (`${DIRH08}/crp/fig/yld_mai_/GSW2__C_19860000.png` (Figure 18), `${DIRH08}/crp/fig/yld_whe_/GSW2__C_19860000.png` (Figure 19), `${DIRH08}/crp/fig/yld_ric_/GSW2__C_19860000.png` (Figure 20))

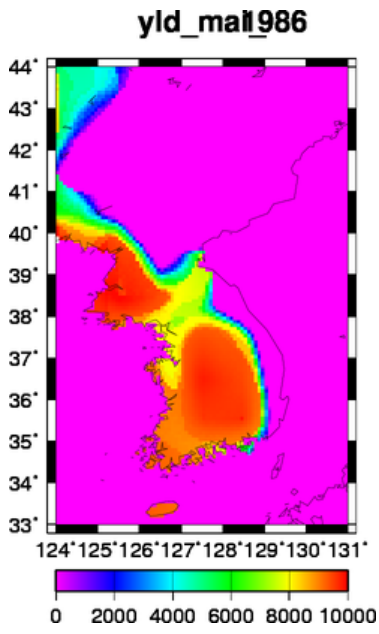


Figure 18. Yield of maize (kg ha<sup>-1</sup>)

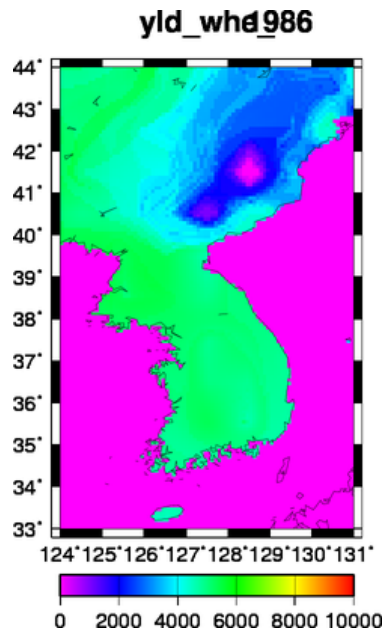


Figure 19. Yield of wheat (kg ha<sup>-1</sup>)

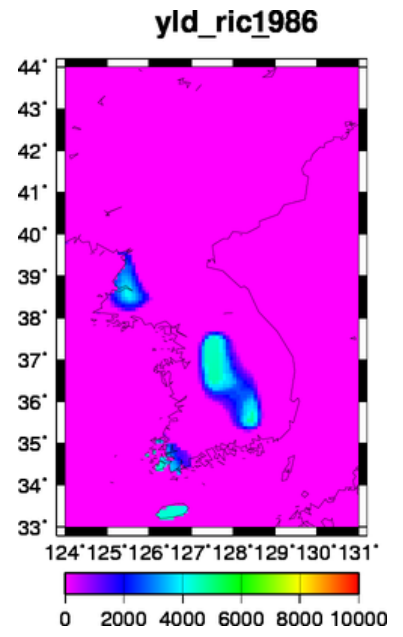


Figure 20. Yield of rice (kg ha<sup>-1</sup>)

## Chapter 6

### Reservoir Module

Following the procedures below, you will be able to setup the files for reservoir operation module.

1. Change directory to  $\{\text{DIRH08}\}/\text{riv}/\text{pst}$  and execute `calc_mean.sh` with the Regional Setting. This results in calculating the monthly and annual mean river discharge.
2. Change directory to  $\{\text{DIRH08}\}/\text{riv}/\text{pst}$  and execute `calc_flddro.sh` with the Regional Setting. This results in identifying the reservoir operating year which is another indispensable information for the reservoir operation module.

## Chapter 7

### Environmental Flow Module

Following the procedures below, you will be able to simulate the environmental flow requirement in Korea.

1. Change directory to  $\{\text{DIRH08}\}/\text{riv}/\text{pst}$  and execute `calc_envout.sh` with the Regional Setting and the parameters shown below. This results in calculating the environmental flow.

YEARMIN=1986 YEARMAX=1986
------------------------------

2. Change directory to  $\{\text{DIRH08}\}/\text{cpl}/\text{pst}$  and execute `list_watbal.sh` with the Regional Setting. Then check the “Environmental (flow)” section. Table 3 shows the estimation of environmental flow.

Table 3. The results of estimation of environmental flow[ $\text{km}^3 \text{y}^{-1}$ ]

Item	Value
Environmental flow	79.60

## Chapter 8

### Coupled Module

Following the procedures below, you will be able to run the coupled model in Korea. First, you will run the N\_C\_ experiment. This estimates agricultural water demand which is an important input of the H08. Then, you will run the N\_C\_ and LECD experiments. These estimate water availability and scarcity of the study domain.

#### 8.1 N\_C\_ experiment

1. Change directory to `${DIRH08}/cpl/pre` and execute `prep.sh` with the Regional Setting. This results in creating the reservoir storage information.
2. Change directory to `${DIRH08}/cpl/bin`. Open `main.f` with text editor and modify the setting of `n01` in order to make the number consistent with that of L.

```
n01=11088
```

3. Compile the main program.

```
% make main
```

4. Change directory to `${DIRH08}/cpl/bin` and execute `main.sh` with the Regional Setting. Make sure that the parameters are set as shown below. This results in calculating the potential agricultural water demand.

```
RUN=N_C_  
LDBG=1 # any integer number not larger than n01  
  
DAMID_=NO  
DAMPRP=NO  
DAMCAP=NO  
DAMMON1ST=NO  
DAMALC=NO  
DAMRIVOUTFIX=NO  
DAMDEMAGRFIX=NO  
  
OPTNNB=YES
```

Before execute Section 8.2 LECD experiment, please execute Section 2.5.

## 8.2 LECD experiment

---

1. Make sure that you have completed all the procedures shown in Section 2.5 (Creating the Map Data Required to Use the Reservoir Module). Change directory to `${DIRH08}/cpl/pre` and execute `prep_mean.sh` with the Regional Setting. This results in calculating the annual mean value of agricultural demand.

(`lnd/out/DemAgr__/GSW2N_C_00000000.ko5`)

2. Change directory to `${DIRH08}/cpl/bin` and execute `main.sh` with the Regional Setting. Additionally, set the parameters as shown below.

```
RUN=LECD
LDBG=1 # any integer number not larger than n01

DAMID_=./../map/dat/dam_id_/H06_____20000000${SUF}
DAMPRP=./../map/dat/dam_prp_/H06_____20000000${SUF}
DAMCAP=./../map/dat/dam_cap_/H06_____20000000${SUF}
DAMMON1ST=./../riv/out/fld2dro_/${PRJLR__}${RUNLR__}0000000
      0${SUF}
DAMALC=./../map/out/dam_alc_/${PRJLR__}${RUNLR__}${SUF}ID
DAMRIVOUTFIX=./../riv/out/riv_out_/${PRJLR__}${RUNLR__}0000
      0000${SUF}
DAMDEMAGRFIX=./../lnd/out/DemAgr__/${PRJN_C_}${RUNN_C_}0000
      0000${SUF}FX

OPTNNB=NO
```

3. Change directory to `${DIRH08}/cpl/pst` and execute `list_watbal.sh` with the Regional Setting. This results in creating the water balance list named `${DIRH08}/tab/wat_bal_/GSW2LR__0000000.yyyy.txt`. Check the “Water balance of the coupled system” section, and make sure that water balance is closed. Table 4 shows that the water imbalance is as small as  $-0.00 \text{ km}^3 \text{ yr}^{-1}$ .

Table 4. Water balance of the coupled system[ $\text{km}^3 \text{y}^{-1}$ ]

Item		Value
Rainfall	+	381.41
Snowfall	+	35.30
Agricultural water supply (Non-local and non-renewable blue water)	-	NA
Industrial water supply (Non-local and non-renewable blue water)	-	NA
Domestic water supply (Non-local and non-renewable blue water)	-	NA
Evapotranspiration	-	209.10
River discharge	-	207.62
Industrial water supply	-	NA
Domestic water supply	-	NA
$\Delta$ Soil moisture	-	0
$\Delta$ Snow water equivalent	-	0
$\Delta$ River storage	-	0
$\Delta$ Reservoir storage	-	NA
$\Delta$ Medium sized reservoir storage	-	NA
Water balance of coupled module		0

## Chapter 9

# Climate Change Simulation

Following the procedures below, you will be able to analyze the impacts of climate change in Korea. Basically, you will re-run all the processes conducted so far with the future climatic conditions.

### 9.1 Data preparation

1. Open a web browser and visit the H08 Global Meteorological Data Server. <http://h08.nies.go.jp/ddc> (user: cmip5 password: CMIP5)
2. Click “Data Downloader” then proceed to “CMIP5”.
3. Set parameters as shown below and click “Download”. The future climate data will be prepared on the server.

```
Dataset          HadGEM2-ES/hg2e(360_day)
Ensemble         rlilpi
Scenarios        rcp85
Temporal resolution Monthly
Variables        tas, pr, rlds 2071-2100
Spatial domain   124,131,33,44
Spatial resolution user defined resolution 84,132,Linear
Meridional sequence North to South(for H08)
File type        Plain binary(little endian) with short
name(for H08 user)
Compress         Yes(gzip compression)
```

4. When all of the requested data are shown on the screen, proceed to “Your Personal Site”. Do NOT download the files manually.
5. Change directory to `${DIRH08}/met/pre` and execute `prep_CMIP3_mean.sh`. Edit the parameters shown below. This script includes automatic download of the files you requested. Note that URL is that of “Your Personal Site”. PID is short for Process ID, which is a number appear at the individual files (e.g. `****tas2071.tar.gz`)

```
PRJ=hg2e
RUN=851_
RUNOUT=851_
YEARMIN=2071
YEARMAX=2100
L=11088
URL=http://h08.nies.go.jp/~ddc/tmp/ddc_data/****
PID=****
```

6. Return to the web browser and visit again the web page for data download. Select like below and click “Download”. The historical climate data will be prepared.

Scenarios	Historical
Variables	tas, pr, rlds 1961-1990

7. When all of the requested data are shown on the screen, proceed to “Your Personal Site”. Do NOT download the files manually.
8. Change directory to `${DIRH08}/met/pre` and execute `prep_CMIP3_mean.sh`. Edit the parameters shown below. Make sure to update PID (and possibly URL).

```
PRJ=hg2e
RUN=hs1_
RUNOUT=hs1_
YEARMIN=1961
YEARMAX=1990
L=11088
URL=http://h08.nies.go.jp/~ddc/tmp/ddc_data/****
PID=****
```

9. Execute `prep_CMIP3_delta.sh` with the Regional Setting and the parameters shown as below. This results in calculating the change (delta) in temperature (in difference), long wave radiation (in difference), and precipitation (in ratio) between the future and historical periods.

```
PRJPRE=hg2e
RUNPRE=hs1_
PRJFUT=hg2e
RUNFUT=851_
```

10. Execute `prep_RH.sh` with the Regional Setting and the parameters shown as below. This results in converting the unit of humidity from specific humidity to relative humidity.

```
PRJ=GSW2
RUN=B1b_
QAIR=../../met/dat/Qair____/${PRJ}${RUN}${SUF}DY
PSURF=../../met/dat/PSurf____/${PRJ}${RUN}${SUF}DY
TAIR=../../met/dat/Tair____/${PRJ}${RUN}${SUF}DY
RH=${DIRRH}/${PRJ}${RUN}${SUF}DY
```

## 9.2 Land surface process module

1. Change directory to  $\{\text{DIRH08}\}/\text{ln}/\text{bin}$  and execute `main.sh` with the Regional Setting and the parameters shown below. The main process of the land surface module will be started.

```

PRJ=hg2e
RUN=LR__

QAIR=NO
RH=../../met/dat/RH_____/GSW2B1b_${SUF}DY
TCOR=../../met/dat/Tair__DF/hg2e851_.binMM
PCOR=../../met/dat/Prcp__RT/hg2e851_.binMM
LCOR=../../met/dat/LWdownDF/hg2e851_.binMM

TAIROUT=${DIRTAIROUT}/${PRJ}${RUN}${SUF}MO
RAINFOUT=${DIRRAINFOUT}/${PRJ}${RUN}${SUF}MO
SNOWFOUT=${DIRSNOWFOUT}/${PRJ}${RUN}${SUF}MO
LWDOWNOUT=${DIRLWDOWNOUT}/${PRJ}${RUN}${SUF}MO

```

2. Change directory to  $\{\text{DIRH08}\}/\text{cpl}/\text{pst}$  and execute `list_watbal.sh` with the Regional Setting and the parameters shown below. Check the “Water balance of land” section, and make sure that water balance is closed. Table 5 shows the water balance of land under the climate change conditions.

```

PRJ=hg2e
RUN=LR__
PRJMET=hg2e
RUNMET=LR__
DIRRAINF=../../ln/out/Rainfout
DIRSNOWF=../../ln/out/Snowfout

```

Table 5. Results of water balance of land under the climate change conditions [ $\text{km}^3 \text{y}^{-1}$ ]

Item	Value	
Rainfall	+	506.25
Snowfall	+	19.60
Agricultural water supply	+	NA
Evapotranspiration	-	282.04
Total runoff	-	243.81
$\Delta$ Soil moisture	-	0.00
$\Delta$ Snow water equivalent	-	0.00
Water balance of land surface	-	0.00

## 9.3 River module

---

1. Change directory to  $\{\text{DIRH08}\}/\text{riv}/\text{bin}$  and execute `main.sh` with the Regional Setting and the parameters shown below. The main process of the river module will be started. This results in creating the river discharge (Figure 21) and river storage (Figure 22) data.

```
PRJ=hg2e
RUN=LR__
YEARMIN=1986
YEARMAX=1986
```

2. Change directory to  $\{\text{DIRH08}\}/\text{cpl}/\text{pst}$  and execute `list_watbal.sh` with the Regional Setting. Check the “Water balance of river” section, and make sure that water balance is closed. Table 6 shows the water balance of river under the climate change conditions.

Table 6. Results of water balance of river under the climate change conditions [ $\text{km}^3 \text{y}^{-1}$ ]

Item		Value
Total runoff	+	243.81
River discharge	-	243.81
Agricultural water supply	-	NA
Industrial water supply	-	NA
Domestic water supply	-	NA
Agricultural water supply (Medium sized reservoir)	-	NA
Industrial water supply (Medium sized reservoir)	-	NA
Domestic water supply (Medium sized reservoir)	-	NA
$\Delta$ River storage	-	0.00
$\Delta$ Reservoir storage	-	NA
$\Delta$ Medium sized reservoir storage	-	NA
Water balance of river		0.00

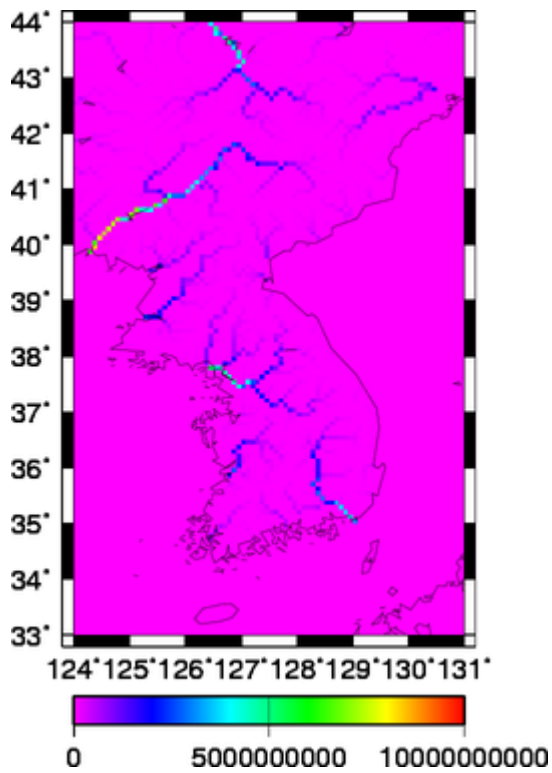


Figure 21. River storage (kg)

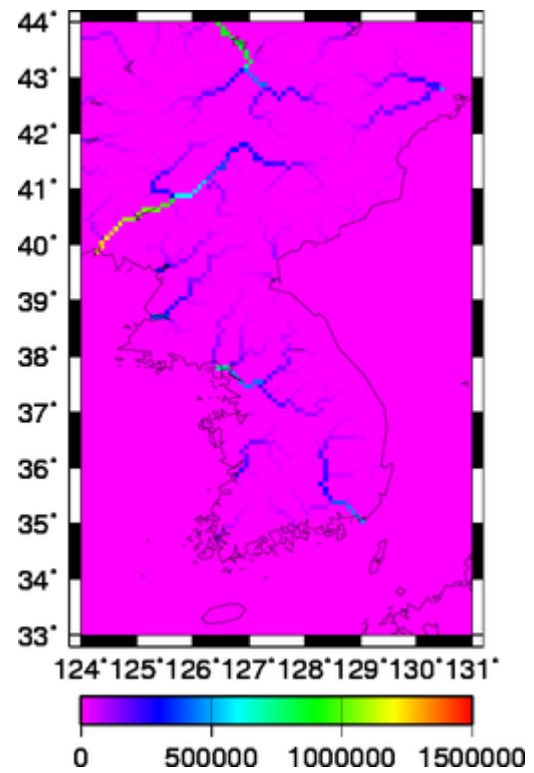


Figure 22. River discharge ( $\text{kg s}^{-1}$ )

## 9.4 Crop growth module

1. Change directory to  $\{\text{DIRH08}\}/\text{crp}/\text{pre}$  and execute `prep.sh` with the parameters below. This results in creating the initial parameter sets.

```

PRJSIM=hg2e
RUNSIM=LR__
PRJMET=GSW2
RUNMET=B1b_
YEARMIN=1986
YEARMAX=1986

```

2. Change directory to `${DIRH08}/crp/bin` and execute `main.sh` with the Regional Setting and the parameters below. This results in calculating the cropping calendars for individual crops under the climate change conditions.

```
JOBS="1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19"
PRJ=hg2e
RUN=__C_

POTEVAP=../../lnd/out/PotEvap_/hg2eLR__${SUF}DY
EVAP=../../lnd/out/Evap_/hg2eLR__${SUF}DY

TCOR=../../met/dat/Tair__DF/hg2e851_.binMM

DIRTAIROUT=../../lnd/out/Tairout_
TAIROUT=${DIRTAIROUT}/${PRJ}${RUN}${SUF}MO
```

3. Change directory to `${DIRH08}/crp/pst` and execute `calc_crpcal.sh` with the Regional Setting and the parameters shown below. This results in creating the cropping calendar of first crop.

```
PRJ=hg2e
RUN=__C_
YEAR=0000
MON=00
DAY=00
```

4. Change directory to `${DIRH08}/crp/bin` and execute `main.sh` with the Regional Setting and the parameters shown below. This results in creating the cropping calendar of second crop.

```
JOBS=" 2nd"
```

5. Change directory to `${DIRH08}/crp/pst` and execute `draw_cryld_map.sh` with the Regional Setting. This results in creating the figure of cropping calendar and yield in `crp/fig`.  
(`${DIRH08}/crp/fig/yld_mai_/hg2e__C_19860000.png` (Figure 23),  
`${DIRH08}/crp/fig/yld_whe_/hg2e__C_19860000.png` (Figure 24),  
`${DIRH08}/crp/fig/yld_ric_/hg2e__C_19860000.png` (Figure 25))

```
PRJ=hg2e
RUN=__C_
YEAR=0000
MON=00
DAY=00
```

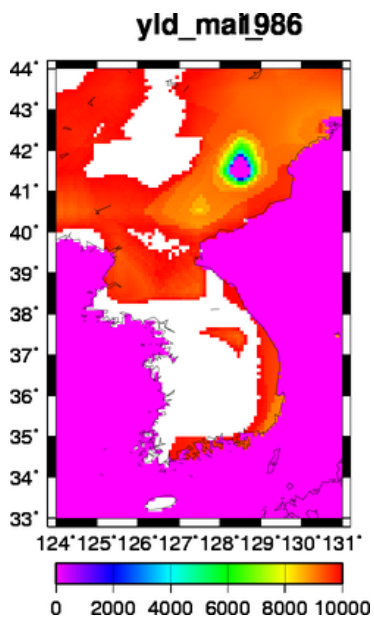


Figure 23. Yield of maize  
(kg ha<sup>-1</sup>)

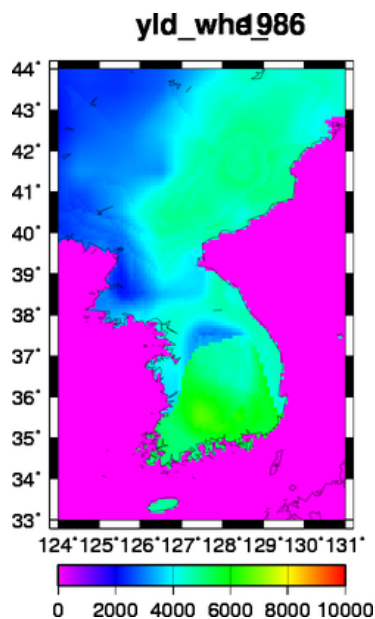


Figure 24. Yield of wheat  
(kg ha<sup>-1</sup>)

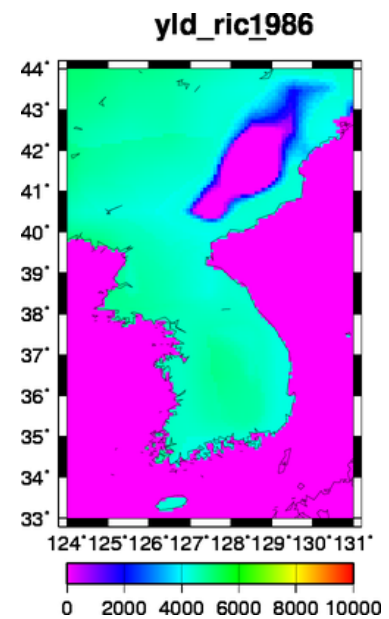


Figure 25. Yield of rice  
(kg ha<sup>-1</sup>)

## 9.5 Inputs for the reservoir module

1. Change directory to `${DIRH08}/riv/pst` and execute `calc_mean.sh` with the Regional Setting and the parameters below. This results in creating the monthly and annual mean river discharge.

```
PRJ=hg2e
RUN=LR__
YEAROUT=0000
```

2. Execute `calc_flddro.sh` with the Regional Setting and the parameters below. This results in creating the storage and release periods information.

```
PRJ=hg2e
RUN=LR__
YEARMIN=0000
YEARMAX=0000
```

## 9.6 Environmental flow module

---

1. Execute `calc_envout.sh` with the Regional Setting and the parameters shown below. This results in calculating the environmental flow.

```
PRJ=hg2e  
RUN=LR__
```

2. Execute `cpl/pst/list_watbal.sh` with the Regional Setting and the parameters shown below. Then check the “Environmental” section of the output file. Table 7 shows the environmental flow under the climate change condition.

```
PRJENV=hg2e  
RUNENV=LR__
```

Table 7. Results of environmental flow under  
the climate change condition[ $\text{km}^3 \text{y}^{-1}$ ]

<u>ENVFLW</u>
<u>94.22</u>

## 9.7 Coupled module(N\_C\_ experiment)

---

1. Change directory to `${DIRH08}/cpl/bin` and execute `main.sh` with the Regional Setting and the parameters shown below.

```
PRJ=hg2e
RUN=N_C_
LDBG=1

PRJMET=GSW2
RUNMET=B1b_
PRJLR__=hg2e
RUNLR__=LR__
PRJ__C_=hg2e
RUN__C_=__C_
PRJN_C_=hg2e
RUNN_C_=N_C_

QAIR=NO
RH=../../met/dat/RH_____/${PRJMET}${RUNMET}${SUF}DY

DAMID =NO
DAMPRP=NO
DAMMON1ST=NO
DAMCAP=NO
DAMSRF=NO
DAMALC=NO
DAMRIVOUTFIX=NO
DAMDEMAGRFIX=NO

OPTNNB=yes
TCOR=../../met/dat/Tair__DF/hg2e851_.binMM
PCOR=../../met/dat/Prcp__RT/hg2e851_.binMM
LCOR=../../met/dat/LWdownDF/hg2e851_.binMM

TAIROUT=${DIRTAIROUT}/${PRJ}${RUN}${SUF}MO
RAINFOUT=${DIRRAINFOUT}/${PRJ}${RUN}${SUF}MO
SNOWFOUT=${DIRSNOWFOUT}/${PRJ}${RUN}${SUF}MO
LWDOWNOUT=${DIRLWDOWNOUT}/${PRJ}${RUN}${SUF}MO
```

## 9.8 Coupled module(LECD experiment)

---

1. Change directory to `${DIRH08}/cpl/pre` and execute `prep_mean.sh` with the Regional Setting and the parameter shown below.

```
PRJ=hg2e
```

2. Change directory to `${DIRH08}/map/bin` and execute `main_dam.sh` with the Regional Setting and the parameter shown below.

```
PRJDIS=hg2e
```

3. Change directory to `${DIRH08}/cpl/bin` and execute `main.sh` with the Regional Setting and the parameters shown below.

```
PRJ=hg2e
RUN=LECD
LDBG=1

DAMID_ = ../../map/dat/dam_id_/H06_____20000000${SUF}
DAMPRP= ../../map/dat/dam_prp_/H06_____20000000${SUF}
DAMCAP= ../../map/dat/dam_cap_/H06_____20000000${SUF}
DAMMON1ST= ../../riv/out/fld2dro_/${PRJLR__}${RUNLR__}0000000
0${SUF}
DAMALC= ../../map/out/dam_alc_/${PRJLR__}${RUNLR__}${SUF}ID
DAMRIVOUTFIX= ../../riv/out/riv_out_/${PRJLR__}${RUNLR__}0000
0000${SUF}
DAMDDEMAGRFIX= ../../lnd/out/DemAgr__/${PRJN_C_}${RUNN_C_}0000
0000${SUF}FX

OPTNNB=NO

TCOR=../../met/dat/Tair__DF/hg2e851_.binMM
PCOR=../../met/dat/Prcp__RT/hg2e851_.binMM
LCOR=../../met/dat/LWdownDF/hg2e851_.binMM

TAIROUT=${DIRTAIROUT}/${PRJ}${RUN}${SUF}MO
RAINFOUT=${DIRRAINFOUT}/${PRJ}${RUN}${SUF}MO
SNOWFOUT=${DIRSNOWFOUT}/${PRJ}${RUN}${SUF}MO
LWDOWNOUT=${DIRLWDOWNOUT}/${PRJ}${RUN}${SUF}MO
```

4. Change directory to `${DIRH08}/cpl/pst` and execute `list_watbal.sh` with the Regional Setting and the parameters shown below. Please check the “Water balance of the coupled system” section. Table 8 shows the water balance of the coupled system under the climate change condition.

```

PRJ=hg2e
RUN=LR__
PRJMET=hg2e
RUNMET=LR__
PRJDEM=hg2e
PRJDEM=N_C_
PRJENV=hg2e
RUNENV=LR__

DIRRAINF=../../lnd/out/Rainfout
DIRSNOWF=../../lnd/out/Snowfout

```

Table 8. Results of water balance of the coupled system under the climate change condition [ $\text{km}^3 \text{y}^{-1}$ ]

Item		Value
Rainfall	+	506.25
Snowfall	+	19.60
Agricultural water supply (Non-local and non-renewable blue water)	-	NA
Industrial water supply (Non-local and non-renewable blue water)	-	NA
Domestic water supply (Non-local and non-renewable blue water)	-	NA
Evapotranspiration	-	282.04
River discharge	-	243.81
Industrial water supply	-	NA
Domestic water supply	-	NA
$\Delta$ Soil moisture	-	0
$\Delta$ Snow water equivalent	-	0
$\Delta$ River storage	-	0
$\Delta$ Reservoir storage	-	NA
$\Delta$ Medium sized reservoir storage	-	NA
Water balance of coupled module		0

# Chapter 10

## Calibration and Validation

This chapter describes how to calibrate the parameters of the land surface module and validate the H08 simulation results with observed river discharge.

There are four parameters that should be calibrated in the land surface model, namely soil depth (SD), CD (the drag coefficient),  $\gamma$ , and  $\tau$ (the shape parameters of sub surface flow). To find the optimal combination of parameters, we are applying the concept of Monte Carlo Method. We are going to test three parameter values for each, and conduct 81 simulation runs altogether (3 x 3 x 3 x 3) and find the parameter set that maximize the score. More details are described in Hanasaki et al. (2014) and Masood et al. (2015).

### 10.1 Preparing data and additional programs/scripts

1. Download and decompress Ind-pre-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{Ind}/\text{pre}$ .
2. Download and decompress Ind-dat-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{Ind}/\text{dat}$ .
3. Download and decompress Ind-bin-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{Ind}/\text{bin}$ .
4. Download and decompress Ind-set-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{Ind}/\text{set}$ .
5. Download and decompress riv-pre-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{riv}/\text{pre}$ .
6. Download and decompress riv-dat-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{riv}/\text{dat}$ .
7. Download and decompress riv-bin-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{riv}/\text{bin}$ .
8. Download and decompress riv-set-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{riv}/\text{set}$ .
9. Download and decompress riv-pst-KOR.tar.gz in  $\{\text{DIRH08}\}/\text{riv}/\text{pst}$ .

Table 9 shows the information of all station.

Table 9. stnlst.SNU.txt

ID	Name	RIV	LON(OBS)	LAT(OBS)	AREA(OBS)	LON(H08)	LAT(H08)	AREA(H08)
1	Gongju	Geum_River	127.14	36.46	7.15E+03	127.13	36.46	7.18E+03
2	Goryeong	Nakdong_River	128.39	35.75	1.40E+04	128.38	35.79	1.46E+04
3	Gyuam	Geum_River	126.89	36.28	8.25E+03	126.88	36.29	7.94E+03
4	Jeokpo	Nakdong_River	128.36	35.53	1.64E+04	128.38	35.54	1.67E+04
5	Moonmak	Seom_River	127.81	37.31	1.34E+03	127.88	37.38	1.57E+03
6	Naju	Yeongsan_River	126.73	35.04	2.06E+03	126.79	35.13	2.10E+03
7	Samrangjin	Nakdong_River	128.83	35.38	2.29E+04	128.79	35.29	2.21E+04
8	Songjeong	Seonjin_River	127.54	35.19	4.27E+03	127.54	35.2	2.24E+03
9	Waegwan	Nakdong_River	128.39	36	1.11E+04	128.38	35.96	1.13E+04
10	Yeoju	Han_River	127.65	37.31	1.11E+04	127.71	37.2	8.67E+03

## 10.2 Calibration

---

1. Change directory to `${DIRH08}/lnd/pre` and execute `prep_genpar.sh` with the Regional Setting. This results in creating parameter files for the Monte Carlo simulation. (`lnd/dat/uniform.*.*.ko5`) The parameters are set as shown below.

Table 10. Parameters for Monte Carlo simulation (81 simulations)

Parameter	Low	Default	High
SD	0.5	1.0	2.0
CD	0.0015	0.003	0.006
tau	50	100	200
gamma	1.0	2.0	4.0

If possible, we recommend testing five parameter values for each, which is shown below, and conduct 625 simulation runs altogether (5 x 5 x 5 x 5).

Table 11. Parameters for Monte Carlo simulation (625 simulations)

Parameter	Lowest	Low	Default	High	Highest
SD	0.5	1.0	2.0	3.0	4.0
CD	0.002	0.003	0.004	0.006	0.008
tau	50	100	150	200	300
gamma	1.5	2.0	2.5	3	4

2. Edit the base simulation setting file `${DIRH08}/lnd/set/GSW2____00000000.set` and `${DIRH08}/riv/set/GSW2____00000000.set`. The simulation parameters other than SD, CD,  $\gamma$ , and  $\tau$  are commonly used in the Monte Carlo simulations.

```
YEARMIN=1986
YEARMAX=1990
```

3. Execute `${DIRH08}/lnd/pre/chparam.sh`. This results in creating 81 simulation setting files for the land surface module with different combinations of SD, CD,  $\gamma$ , and  $\tau$ . (`lnd/set/GSW2AAAA${DATA}.set~CCCC${DATA}.set`)
4. Change directory to `${DIRH08}/lnd/bin` and execute `loop.sh`. This shell script manages 81 simulations of the land surface module.
5. Change directory to `${DIRH08}/riv/pre` and execute `chparam.sh`. This results in creating 81 simulation setting files for the river module. (`riv/set/GSW2AAAA20151002.set~CCCC20151002.set`)
6. Change directory to `${DIRH08}/riv/bin` and execute `loop.sh`. This shell script manages 81 simulations of the river module.
7. Make sure whether `htmtext` and `htstatlst` exist in `${DIRH08}/bin`. H08\_20130501 and earlier versions may not include `htmtext` and `htstatlst`. If this is the case, follow the instruction shown in the “Bugs & Update” page of the H08 website ([http://h08.nies.go.jp/h08/bugs\\_update.html](http://h08.nies.go.jp/h08/bugs_update.html)).

8. Change directory to  $\{\text{DIRH08}\}/\text{riv}/\text{pst}$  and execute `calc_evldis.sh`. This shell script evaluates the score of 81 individual simulations for each river gauging station. This results in determining the best combination of parameters (SD, CD, CAMMA, TAU) and calculating the score (i.e. NSE (Table 10)).  
(riv/out/par\_cmb\_/GSW2.txt, riv/out/riv\_dis\_/GSW2AAAA00000001~CCC00000010.txt)

Table 12. Value range and evaluation of the Nash-Sutcliffe Efficiency (NSE)

Value range	Evaluation
$\text{NSE} < 0$	Poor
$0 \leq \text{NSE} < 0.5$	Moderate
$0.5 \leq \text{NSE}$	Good

9. Change directory to  $\{\text{DIRH08}\}/\text{Ind}/\text{pre}$  and execute `prep_optpar.sh`. This script generates the geographical maps of the optimized parameters. Check your results are identical to Figure 26-29. Now you are ready to run H08 with calibrated parameters.  
(Ind/dat/GSW2.sd.ko5(Figure 26), Ind/dat/GSW2.cd.ko5(Figure 27),  
Ind/dat/GSW2.gamma.ko5(Figure 28), Ind/dat/GSW2.tau.ko5(Figure 29),  
map/out/sub\_bsn\_/\_\_\_\_\_00000001.ko5~00000010.ko5)

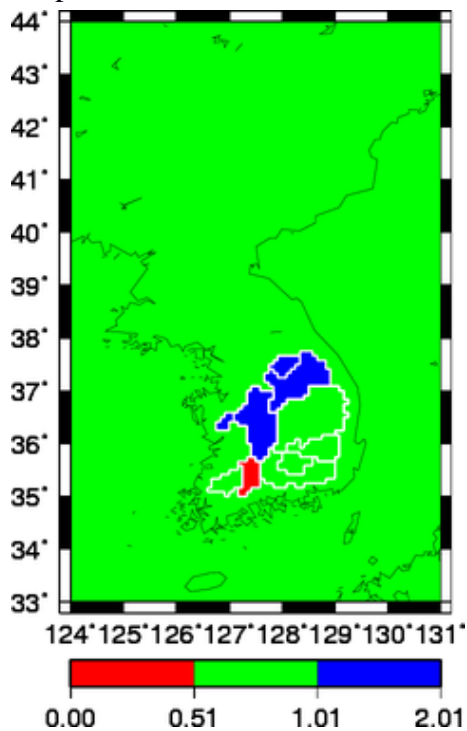


Figure 26. SoilDepth

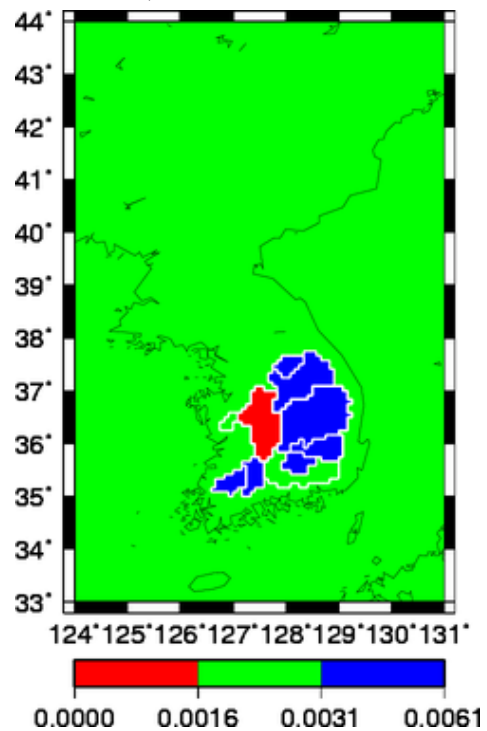


Figure 27. CD

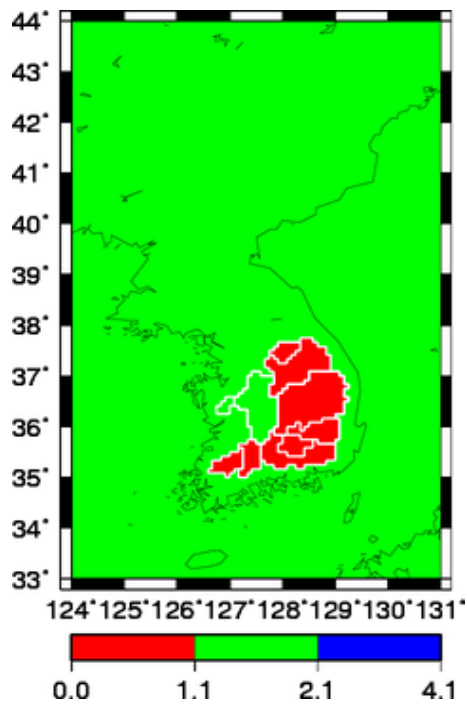


Figure 28. GAMMA

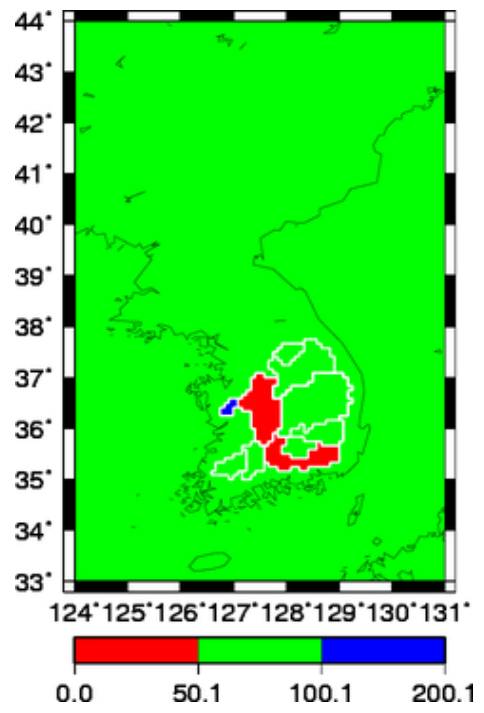


Figure 29. TAU

NSE

NSE (Nash-Sutcliffe Efficiency) is a widely used index to evaluate the performance of hydrological simulations. It is defined as follows (Nash and Sutcliffe, 1970).

$$NSE = 1 - \frac{\sum_{i=1}^n (Q_i - Q'_i)^2}{\sum_{i=1}^n (Q_i - \bar{Q})^2}$$

Here,  $Q_i$  is observed discharge at time  $i$ ,  $Q'_i$  is simulated discharge at time  $i$ ,  $\bar{Q}$  is the mean observed discharge. NSE ranges from  $-\infty$  to 1. Simulations are considered 'good' when NSE exceeds 0.5 (Moriassi et al., 2007). NSE takes 0 when  $Q'_i = \bar{Q}$  or the timeseries of simulation are identical to the mean observed discharge. Simulations are considered 'poor' when NSE falls below 0 or when they perform worse than the constant mean observed discharge.

To better understand this index, the NSE values are calculated for the following function  $y$  and shown in Figure 30.

$$y = a \times \sin\left(\frac{x + b}{6}\right)\pi + c$$

Here,  $x$  is month, and  $y$  is the discharge. We assume that  $a=1$ ,  $b=0$ , and  $c=1.5$  are the time series of observed discharge. Figure 30 (a) shows an example of the simulation when  $a=1$ ,  $b=0$ ,  $c=1.5$  (i.e. the simulation perfectly matches with observation). In this case, NSE takes 1. Figure 30 (b) shows the case  $a=1$ ,  $b=1$ , and  $c=1.5$  (i.e. the phase delays by one month). For this case, NSE takes 0.73. Figure 30 (c) shows the case  $a=1.5$ ,  $b=0$ , and  $c=1.5$  (i.e. the amplitude is 1.5 times of the observation). For this case, NSE takes 0.75. Figure 30 (d) shows the case  $a=1.5$ ,  $b=1$ , and  $c=1.5$  (i.e. the amplitude is 1.5 times of the observation and the phase delays by one month). For this case, NSE takes 0.35.

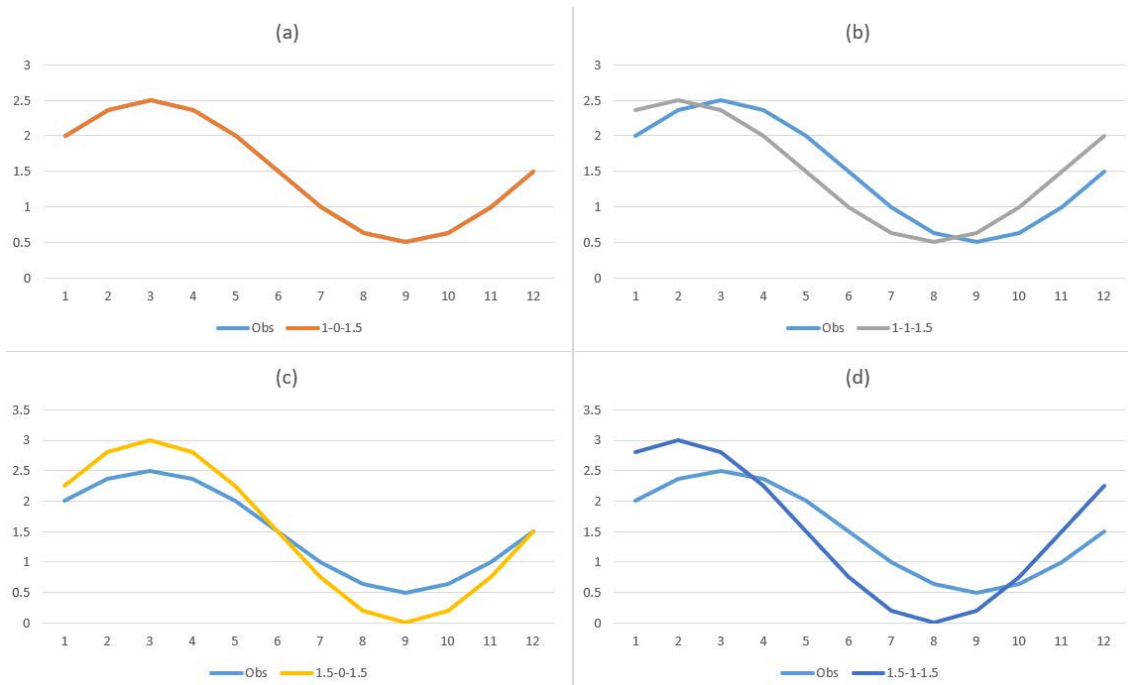


Figure 30 (a) Simulation ( $a=1$ ,  $b=0$ ,  $c=1.5$ ) perfectly agree with observation. (b) The phase differs by one month ( $a=1$ ,  $b=1$ ,  $c=1.5$ ). (c) The magnitude of amplitude differs by 1.5 times ( $a=1.5$ ,  $b=0$ ,  $c=1.5$ ). (d) The phase and the magnitude of amplitude differs by one month and 1.5 times, respectively ( $a=1.5$ ,  $b=1$ ,  $c=1.5$ ).

## 10.3 Validation

---

1. Change directory to `${DIRH08}/lnd/bin` and execute `main.sh` with the Regional Setting and the parameters shown below. The land surface module with the optimal parameter set will be executed. Note that the validation period is set to 1991-1995, which is different from the calibration period.

```
PRJ=GSW2
RUN=VALI
YEARMIN=1991
YEARMAX=1995
SOILDEPTH=../../../../lnd/dat/GSW2.sd.ko5
CD=../../../../lnd/dat/GSW2.cd.ko5
GAMMA=../../../../lnd/dat/GSW2.gamma.ko5
TAU=../../../../lnd/dat/GSW2.tau.ko5

Qair=../../../../met/dat/Qair____/GSW2B1b_${SUF}DY
RH=NO

TCOR=NO
PCOR=NO
LCOR=NO

TAIROUT=NO
RAINFOUT=NO
SNOWFOUT=NO
LWDOWNOUT=NO
```

2. Change directory to `${DIRH08}/riv/bin` and execute `main.sh` with the Regional Setting and the parameters shown below. The river module with the optimal parameter set will be executed.

```
(riv/out/riv_out_/GSW2VALIYYYYMMDD.ko5,
riv/out/riv_sto_/GSW2VALIYYYYMMDD.ko5)
```

```
PRJ=GSW2
RUN=VALI
YEARMIN=1991
YEARMAX=1995
```

3. River discharge simulation is outputted to `${DIRH08}/riv/out`. Compare output data (`riv_out_`) with observed river discharge data. Note that observed data is located as shown in Table 11.

Table 13 Paths of the observed river discharge data

Item	Paths
Daily river discharge	$\{\text{DIRH08}\}/\text{riv}/\text{dat}/\text{riv\_disD}/\text{SNU\_v1\_00000001.txt}\sim\{00000010.txt}$
Monthly river discharge	$\{\text{DIRH08}\}/\text{riv}/\text{dat}/\text{riv\_disM}/\text{SNU\_v2\_00000001.txt}\sim\{00000010.txt}$

Figures 31-40 show the simulated and observed river discharge at ten stations. NSE for the calibration and validation periods are also shown. NSE exceeds 0.5 except Moonmak in the Seom River (Figure 35), Naju in the Yeongsan River (Figure 36), and Yeosu in the Han River (Figure 40) in the calibration period. Particularly, the simulation at Moonmak in the Seom River is considerably different from observation which requires further investigation that are behind the observation. For most cases, simulations in the calibration period outperformed those in the validation.

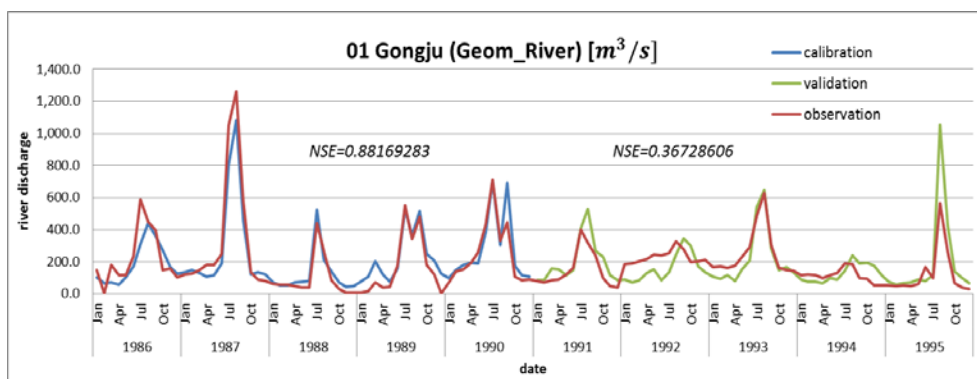


Figure 31. River discharge of Gongju in the Geom River

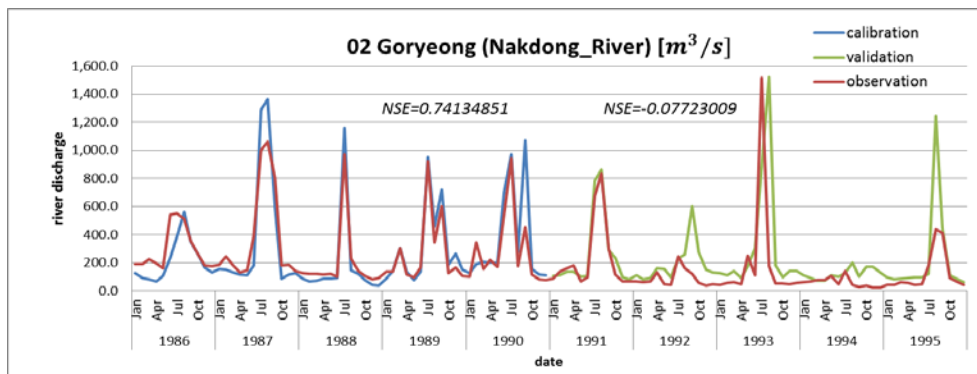


Figure 32. River discharge of Goryeong in the Nakdong River

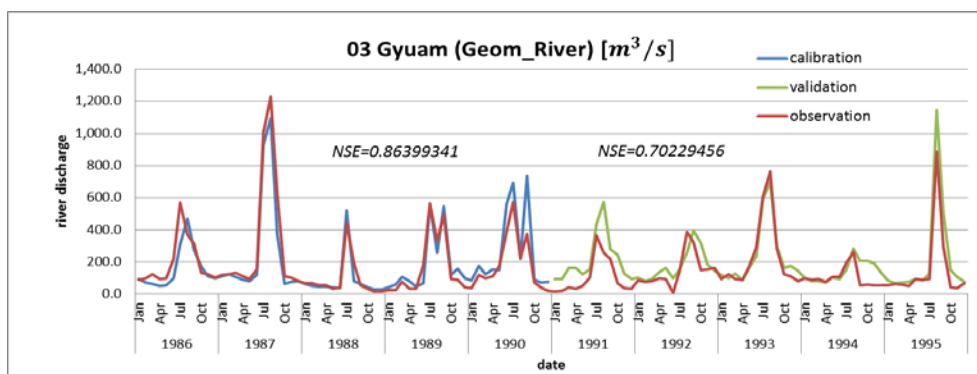


Figure 33. River discharge of Gyuan in the Geom River

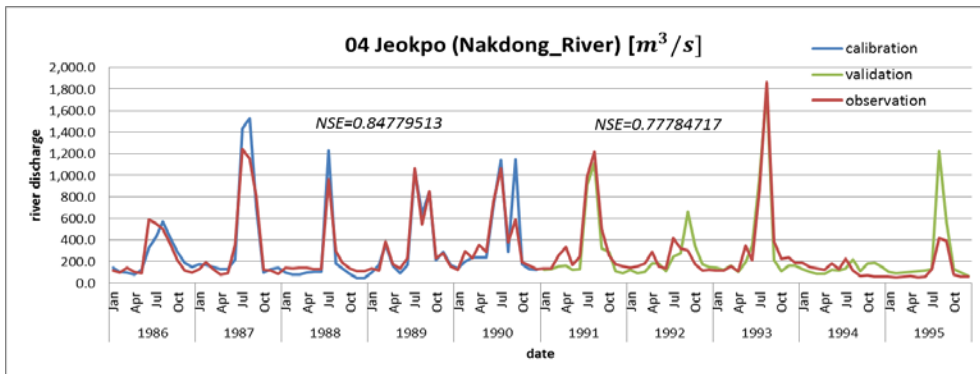


Figure 34. River discharge of Jeokpo in the Nakdong River

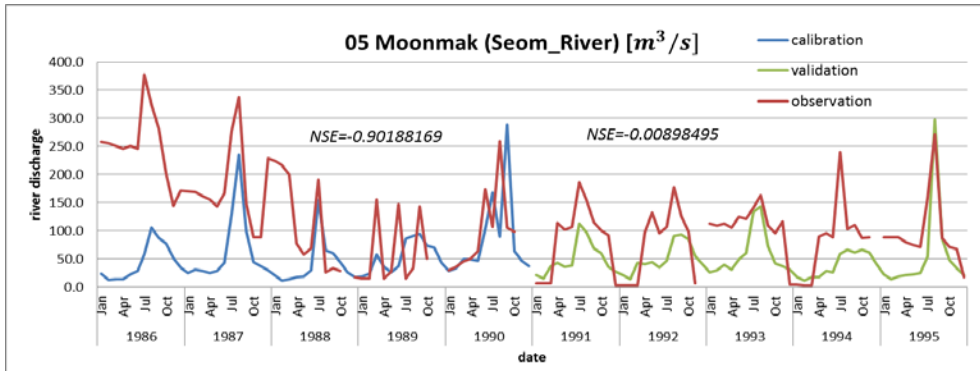


Figure 35. River discharge of Moonmak in the Seom River

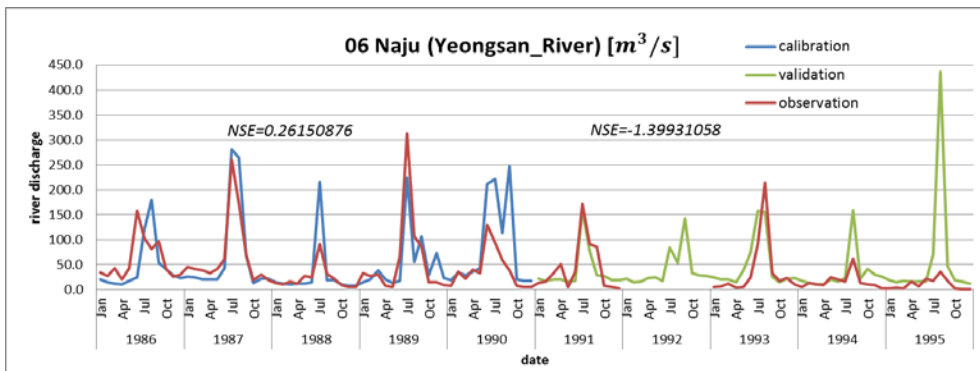


Figure 36. River discharge of Naju in the Yeongsan River

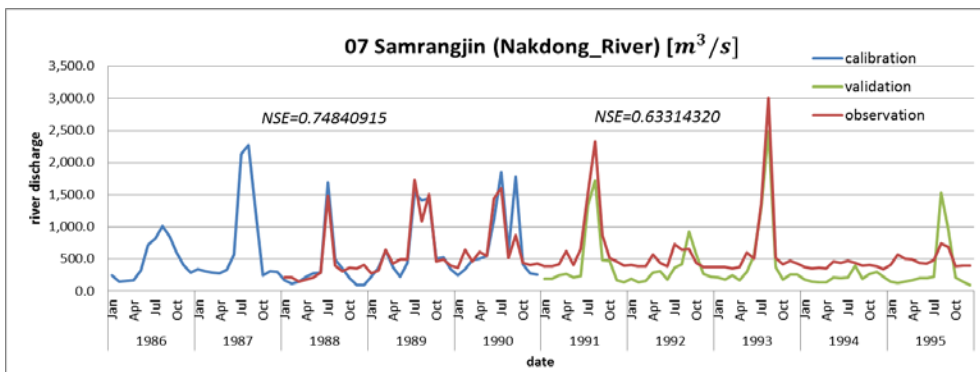


Figure 37. River discharge of Samrangjin in the Nakdong River

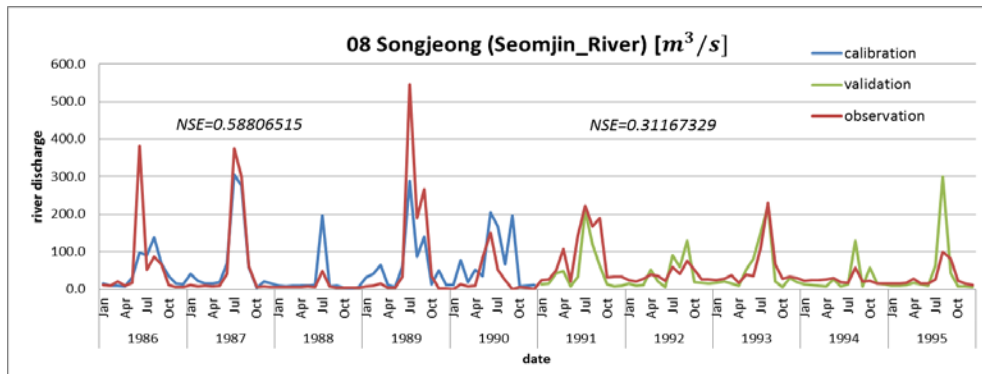


Figure 38. River discharge of Songjeong in the Seomjin River

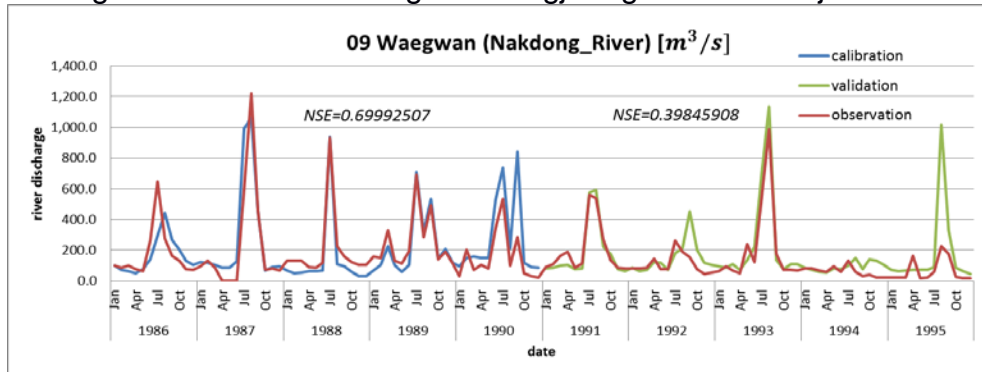


Figure 39. River discharge of Waegwan in the Nakdong River

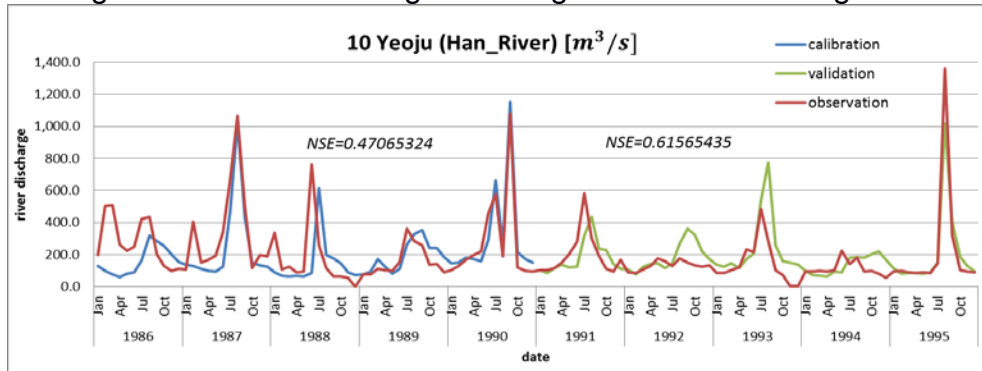


Figure 40. River discharge of Yeoju in the Han River

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