H08 Manual
User's Edition

Supplement 1: Regional Application
- Case Study of the Chao Phraya River

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Version information

See http://h08.nies.go.jp/ for H08 version information.

July 1, 2012	Additional source code and manual Ver. 20120701 released (Compatible with H08 Ver20120101)
May 1, 2013	Additional source code and manual Ver. 20130501 released (Compatible with H08 Ver20130501, Base map changed from K10 to K10S)
Aug 1, 2013	Added Appendix A and B.

Contents

Chapter 1
Introduction
Introduction

1.1 Introduction

This note was prepared in order to run H08 for the Chao Phraya River at 5 minutes x 5 minutes spatial resolution. For this simulation, you need the standard environment of H08, meteorological and geographical data, and additional H08 components.

To set up standard environment of H08, refer to the H08 website.[1] Note that this textbook is compatible to Version H08_20120101 and later.

The meteorological and geographical data for this basin is available at H08 data server. The data was developed by Mr. Shunji Kotsuki and Prof. Kenji Tanaka at Kyoto University. The dataset is referred as K10, short for Kotsuki et al. (2010). When use this textbook, don't forget to cite their article.

This textbook is prepared for those who completed the "H08 User's manual" (Hanasaki and Yamamoto, 2010) which explained in detail how we can run H08 at 1 degree x 1degree globally. This textbook basically shows which procedures you need to change from Hanasaki and Yamamoto (2010) to run H08 for this spatial domain and resolution. The authors strongly recommend you to go through Hanasaki and Yamamoto (2010) before and during reading this manual.

[1] http://h08.nies.go.jp

Chapter 2
Simulation Overview
Simulation Overview

2.1 Simulation Overview

In this text, we will conduct four simulations as shown in Table 2-1

Table 2-1 Simulation list

Name	Description
K10dLR__	H08 simulation **without** reservoir operation. The parameters for land surface module are **default**.
K10oLR__	H08 simulation **without** reservoir operation. The parameters for land surface module are **optimized**.
K10oLRDh	H08 simulation **with** reservoir operation. The parameters for land surface module are **optimized**.
mm23LR__	H08 simulation **without** reservoir operation. The parameters for land surface module are **optimized**. Climate scenario of MIROC3.2medres A2 2070-2099 is used.

This text explains to simulate for the year 1981 only, but of course the users can extend the period.

Chapter 3 Installation

3.1 H08 Install

1. Use H08 installation files H08_20120101.tar.gz or later. First copy this file to the directory in which you want to install the program.
2. Uncompress the file.

```
% gunzip H08_20120101.tar.gz
% tar xf H08_20120101.tar
```

3. Move to directory H08_20120101.
4. Execute install.sh as follows:

```
% sh install.sh
```

5. After a short while, installation will end with message of two lines.
6. Create a file named “Mkinclude” in the directory “adm”. You can copy and use for example Makeinclude.Mac.
7. Edit Mkinclude. You MUST set FC (path and options of Fortran compiler). You SHOULD set INC (path to the NetCDF include file) and LIB (path to the NetCDF library file) as well, but just leave them as they are if you don’t understand what these mean. INC and LIB are only used to convert standard H08 input/output files into NetCDF files, which is optional.
8. Once you have created the Mkinclude file in the adm directory, execute install.sh once again. This will result in the compilation of all the programs.

3.2 H08 Preference

Follow Chapter 3.2 "H08 Preference” in Hanasaki and Yamamoto (2010). Confirm whether you can find “export LCP5=5040” in your preferences file. Don’t forget to change DIRH08 to the currently using one if you have multiple H08 versions.

Chapter 4 H08 Directory Structure
H08 Directory Structure

There is no change from Hanasaki and Yamamoto (2010).

Chapter 5 H08 INPUT/OUTPUT Files
H08 INPUT/OUTPUT Files

There is no change from Hanasaki and Yamamoto (2010).

Chapter 6
Creating Map Data

6.1 Creating H08 basic spatial information

1. Change directory to map/pre
2. Edit prep_basmap.sh. Change L=5040, XY=”60 84”, LONLAT=”97 102 13 20”, SUF=.cp5.
3. Execute prep_basmap.sh as follows.

```
% sh prep_basmap.sh
```

・Column 1

● Checking Map Data

If you want to know the sum of all cells, or in other words, the surface are of the whole domain,

```
% cd ${DIRH08}/map/pre
% sumcp5 ../../map/dat/grd_ara_/grdara.cp5
```

Note that in global 1degree simulation, we used “sumone”, but for this domain, we use “sumcp5”. You should obtain 4.13×10^{11} as a result. If you want to know the maximum (or minimum) area of each cell,

```
% maxcp5 ../../map/dat/grd_ara_/grdara.cp5
% mincp5 ../../map/dat/grd_ara_/grdara.cp5
```

Again note that in global 1degree simulation, we used “maxone” and “minone”, but for this domain and resolution, we use “maxcp5” and “mincp5” respectively. If you want to draw a map of this domain, you can easily do so by,

```
% makecpt –T80000000/85000000/1000000 –Z > temp.cpt
% cp52eps ../../map/dat/grd_ara_/grdara.cp5 temp.cpt
                                                temp.eps
% htconv temp.eps temp.png rot
% display temp.png
```

6.2 Creating the Map Data Required to Use the Land Surface Module

1. Download map-org-K10S.tar.gz[2] from the file server (TOP > h08model > IMPAC-T > data_map_and_source_code).
2. Put the file to map/org. If you don't have map/org, then make a new directory. Then uncompress it.
3. Change directory map/pre.
4. Download map-pre-K10S.tar.gz from the file server. Put it to map/pre and uncompress it. This results in the creation of a subdirectory map-pre-K10S. Move the all files in map/pre/map-pre-K10S to map/pre by

```
% mv map-pre-K10S/* .
```

5. Edit and execute prep_lnd_K10S.sh (actually, you don't need to edit this script at all, for this exercise). Now you will have a file map/dat/lnd_ara_/lndara.K10S.cp5.

6.3 Creating the Map Data Required to Use the River Module

1. Change directory to map/bin
2. Edit and execute main_riv.sh. Edit "Geographical settings" as below.

```
L=5040
XY="60 84"
LONLAT="97 102 13 20"
L2X=../../map/dat/l2x_l2y_/l2x.cp5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.cp5.txt
SUF=.cp5
MAP=.K10S
LDBG=3098
```

See Table 5-1 of Hanasaki and Yamamoto (2010) for abbreviations.

6.4 Creating the Map Data of National Border and Population

Below can be proceeded only if you have completed the settings of the global model. If you have not yet done, follow the instructions in Chapter 6 of the H08 Manual User's Edition.

1. Change directory to map/pre.
2. Edit and execute prep_map_AQUASTAT.sh with L=9331200 and SUF=.gl5.
3. Edit and execute prep_map_region.sh.

[2] H08 Server: https://fxp.nies.go.jp (user: h08model, password: H08model). See the page of "IMPAC-T"

6.5 Creating the Map Data Required to Use the Crop Growth Module

Execute contents up to Chapter 6 of the H08 Manual User's Edition.

1. Change directory map/pre.
2. Edit and execute prep_crp_rigion.sh.
3. Change directory map/bin.
4. Edit and execute calc_crptyp.sh.
5. Edit and execute calc_crpfrc.sh

6.6 Creating the Map Data Required to Use the Reservoir Module

1. For this simulation, you don’t need to carry out the processes up to Chapter9: you can start this process now.
2. Download the original data map-org-H06.tar.gz[3]. Put the file to map/org, and uncompress it. The file damlst.K10.cp5.txt includes the file to set the location and specification of reservoirs for this study domain. The file contains 19 records. For example, the first line shows below. If you wish to add a reservoir, add and complete a new line.

```
99.04166      longitude
17.20833      latitude
1             ID
OK            “OK” to include, “NG” to omit
Bhumibol      The name of reservoir
Thailand      Country
1964   Year constructed
Ping   Name of River at dam site
ChaoPhraya    Name of River at river mouth
9662   Storage capacity in [10^6m^3]^1
26382  Catchment area [km^2]
2             Priority of hydropower generation
4             Priority of water supply
3             Priority of flood control
1             Priority of irrigation water supply
0             Priority of navigation
0             Priority of other purposes
128           Surface area [km^2]
```

3. Change directory to map/pre/.
4. Edit and execute prep_dam_H06.sh (Edit Geographical settings, same as above).
5. For this simulation, you don’t need to carry out process 5 and 6.

[3] Note that this is same as the files for global simulations.

6.7 Creating the Map Data Required to Use the Water Withdrawal Module

You don't need to prepare water withdrawal data since this is already done in 6.4..

Chapter 7 Meteorological Data
Meteorological Data

7.2 Preparing Meteorological Data

1. Change directory to met/pre
2. Download met-pre-K10.tar.gz. Put it to met/pre, and uncompress it. This process results in the creation of a subdirectory met-pre-K10. Move the all files in met/pre/met-pre-K10 to met/pre by

   ```
   % mv met-pre-K10/* .
   ```

   Because the files contain Fortran source code files, compile again by

   ```
   % make clean
   % make all
   ```

3. Download K10 meteorological data files from the data server, and save them at met/org/K10. See the instruction in prep_K10.sh. Actually, H08 needs eight meteorological variables (Table 7-2), although because K10 data does not separate precipitation into rainfall and snowfall, we just need to download seven files.
4. Edit and execute prep_K10.sh (Actually, you don’t need to edit this script at all, this time basically).
5. Download met-org-K10_Albedo.tar.gz. Put it to met/org, and uncompress it. Change directory met/org/K10_Albedo, and execute cp.sh.

Table 7-2 Meteorological data file names

Variables	K10	GSWP2
Surface air temperature	Tair1981_3hr_Thai.gad.gz	Tair…
Specific humidity	qair1981_daily_Thai.gad.gz	Qair…
Wind speed	wind1981_1hr_Thai.gad.gz	Wind…
Surface air pressure	pssf1981_1hr_Thai.gad.gz	PSurf…
Shortwave downward radiation	ssrd1981_3hr_Thai.gad.gz	SWdown…
Longwave downward radiation	slrd1981_3hr_Thai.gad.gz	LWdown…
Rainfall	APrec1981_1hr_thai_5min.gad.gz	Rainf…
Snowfall		Snowf…

・Column 3

● Checking Map Data

If you want to obtain the data at Nakhon Sawan (E100.11, N15.67), enter:

```
% cd met/dat/Tair____
% punchcp5 lonlat ./K10_____.cp5DY 1981 1981 100.11 15.67
```

If you wish to convert daily data into monthly,

```
% mon2yearcp5 ./K10_____.cp5DY 1981 1981 ./K10_____.cp5MO
% punchcp5 lonlat ./K10_____.cp5MO 1981 1981 100.11 15.67
```

Chapter 8
Land Surface Process Module

8.3 Preprocessing

1. Change directory lnd/pre.
2. Edit prep.sh (Change geographical settings only, and leave remaining settings as is).
3. Execute prep.sh. This results in the outputting of parameters in lnd/dat, and initial values for state variables in lnd/ini.
4. Again, edit prep.sh. This time, set

```
V_SOILDEPTH=3.00
V_CD=0.006
V_GAMMA=2.30
V_TAU=120.00
```

   These are optimized parameters set found by Ms. Cherry Mateo for this simulation settings.
5. Execute prep.sh. This results in the outputting of the other parameter files in lnd/dat.

8.4 Main process

1. Change directory to lnd/bin
2. Edit main.sh. First, let’s setup K10dLR__ simulation (See Table 2-1),

```
PRJ=K10d
RUN=LR__
YEARMIN=1981
YEARMAX=1981
SECINT=86400
LDBG=3098     # C2: Nakhon Sawan
SUF=.cp5
MAP=.K10S
WIND=../../met/dat/Wind____/K10_____${SUF}DY
RAINF=../../met/dat/Rainf___/K10_____${SUF}DY
SNOWF=../../met/dat/Snowf___/K10_____${SUF}DY
TAIR=../../met/dat/Tair____/K10_____${SUF}DY
QAIR=../../met/dat/Qair____/K10_____${SUF}DY
RH=NO
PSURF=../../met/dat/PSurf___/K10_____${SUF}DY
SWDOWN=../../met/dat/SWdown__/K10_____${SUF}DY
LWDOWN=../../met/dat/LWdown__/K10_____${SUF}DY
BALBEDO=../../met/dat/Albedo__/GSW2____${SUF}MM
```

3. Afterwards, edit main.f (change n0l=5040), and compile,

```
% make main
```

4. Execute main.sh. Now you will get output files with default parameters
5. Again, edit main.sh. Second, let's setup K10oLR__ simulation (See Table 2-1),

```
PRJ=K10o
SOILDEPTH=../../lnd/dat/uniform.3.00${SUF}
CD=../../lnd/dat/uniform.0.006${SUF}
GAMMA=../../lnd/dat/uniform.2.30${SUF}
TAU=../../lnd/dat/uniform.120.00${SUF}
```

6. Execute main.sh. Now you will get output files with optimized parameters.

8.5 Postprocess

1. Change directory cpl/pst
2. Edit and execute list_watbal.sh. First, let's check the water balance of K10dLR__ simulation.

```
PRJ=K10d
RUN=LR__
PRJMET=K10_
RUNMET=____
YEAR=1981
YEARINI=1980
YEAREND=1981
L=5040
XY="60 84"
LONLAT="97 102 13 20"
L2X=../../map/dat/l2x_l2y_/l2x.cp5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.cp5.txt
SUF=.cp5
MAP=.K10S
```

3. Again edit and execute list_watbal.sh. Second, let's check the water balance of K10oLR__ simulation.

```
PRJ=K10o
RUN=LR__
```

Chapter 9
River Module

9.3 Preprocessing

1. Change directory to riv/pre
2. Edit and execute prep.sh. Change geographical settings.

9.4 Calculation

1. Change directory to riv/bin.
2. Edit main.sh for K10dLR__ simulation.

```
PRJ=K10d
RUN=LR__
YEARMIN=1981
YEARMAX=1981
SECINT=86400
LDBG=3098
SUF=.cp5
MAP=.K10S
```

   Afterwards, edit main.f (change n0l=5040), and compile,

```
% make main
```

3. execute main.sh
4. Again edit and execute main.sh for K10oLR__ simulation.

```
PRJ=K10o
RUN=LR__
```

9.5 Postprocessing

1. Change directory cpl/pst
2. Edit and execute list_watbal.sh

9.6 Validation (not appeared in Hanasaki and Yamamoto, 2010)

1. Download riv-org-RID.tar.gz. Put it to riv/org, and uncompress it[4].
2. Download riv-pre-RID.tar.gz. Put it to riv/pre and uncompress it. This results in the creation of a subdirectory riv-pre-RID. Move the all files in riv/pre/riv-pre-RID to riv/pre by

```
% mv riv-pre-RID/* .
```

   Because the files contain Fortran source code files, compile again by

```
% make clean
% make all
```

3. Check the files in riv/org/RID and edit input/output file argument in prep_RID.sh.
4. Execute prep_RID.sh. This results in outputting H08 Format 1D reformatted data of RID river discharge data in riv/dat/riv_dis_[5].

Table 9-3 Location of major stations in the Chao Phraya River

	C2	Bhumibol	Sirikit	Y6	W4A
Observed catchment area [km^2]	109973	26400	13130	12769	10493
Observed Longitude (corresponding x coordinate)	100.11 (38)	99.02 (25)	100.55 (43)	99.79 (34)	99.1 (26)
Observed Latitude (corresponding y coordinate)	15.67 (52)	17.25 (34)	17.77 (27)	17.43 (31)	17.21 (34)
K10S catchment area for observed lon & lat [km^2]	114001	26943	13693	13071	10561

[4] The files were provided by Mr. Somkid Saphaokham and Mr. Thada Sukkapan,of Thai Royal Irrigation Department (RID). The file format is standard hydrological data of RID.

[5] If you wish to convert daily data into monthly, go to riv/dat/riv_dis_, and use
% httimetxt ./rivdis_C2.txtDY ./rivdis_C2.mon.txtMO
This results in creating a file rivdis_C2.mon.txt with monthly data.

• Column 4

● Draw a hydrograph comparing two simulations and observation

Prepare daily discharge data of K10dLR__ simulation. For example, if we make a hydrograph at Nakhon Sawan (C2 Station, lon/lat=100.11/15.67)

```
% cd ../../riv/out/riv_out_/
% mon2yearcp5 ./K10dLR__.cp5DY 1981 1981 ./K10dLR__.cp5MO
% punchcp5 lonlat ./K10dLR__.cp5MO 1981 1981 100.11 15.67 >
K10dLR__.C2.txt
```

Prepare daily discharge data of K10oLR__ simulation

```
% mon2yearcp5 ./K10oLR__.cp5DY 1981 1981 ./K10oLR__.cp5MO
% punchcp5 lonlat ./K10oLR__.cp5MO 1981 1981 100.11 15.67 >
K10oLR__.C2.txt
```

Observed data is already prepared in ${DIRH08}/riv/dat/riv_dis_
Draw a graph using MS Excel, OpenOffice Calc, and others.

Draw a graph using H08 Analysis Tools.

```
% htcatts K10dLR__.C2.txtMO K10oLR__.C2.txtMO > temp.txt
% htdrawts temp.txt temp.eps -R1/12/0/6000000 -JX10/10
      -Ba1g1:Month:/a1000000g1000000:rivout_[kg/s]:neWS
                                                  C2_hydrograph 2
% htconv temp.eps temp.png rot
```

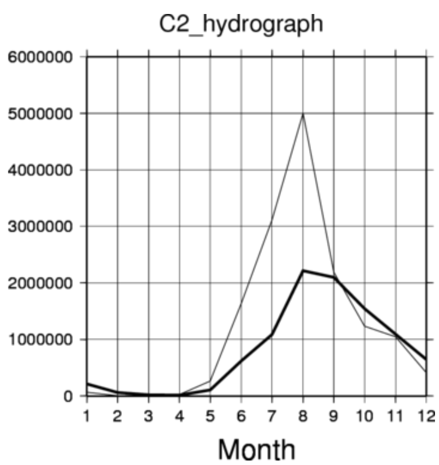


Figure 9-1 C2 hydrograph

Chapter 10 Crop Growth Module
Crop Growth Module

See H08 Manual User’s Edition.

10.3 Preprocessing

1. Change directory crp/pre
2. Edit and execute prep.sh.

```
L=5040
XY=”60 84”
L2X=../../map/dat/l2x_l2y_/l2x.cp5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.cp5.txt
LONLAT="97 102 13 20"
SUF=.cp5
PRJSIM=K10o  # or K10d
RUNSIM=LR__
PRJMET=K10_
RUNMET=____
YEARMIN=1981
YEARMAX=1981
YEAROUT=0000
```

3. Get crp-org-SWIM.tar.gz from H08 file server and put the file crp/org/SWIM.
4. Uncompress the files.

```
% gunzip crp-org-SWIM.tar.gz
% tar xf crp-org-SWIM.tar
```

10.4 Main process

1. Change directory crp/bin.
2. Edit main.sh as follows.

```
PRJ=K10d     # or K10o
RUN=__C_
YEAR=1981
LDBG=3098
L=5040
SUF=.cp5
MAP=K10S
POTEVAP=../../lnd/out/PotEvap_/${PRJ}LR__${SUF}DY
   EVAP=../../lnd/out/Evap____/${PRJ}LR__${SUF}DY
```

Afterwards, edit main.f (change n0l=60*84 and n0llnd=1936), and compile,

```
% make main
```

3. Execute main.sh.
4. Change directory crp/pst
5. Edit and execute calc_crpcal.sh.

```
PRJ=K10d     # or K10o
RUN=__C_
YEAR=1981
```

6. Change directory crp/bin.
7. Edit and execute main.sh with JOBS=2nd.

10.5 Postprocessing

1. Change directory crp/pst.
2. Edit and execute draw_crpyld_map.sh.

```
PRJ=K10d     # or K10o
RUN=__C_
YEAR=1981
```

Chapter 11 Reservoir Operation Module
Reservoir Operation Module

Reservoir operation module (not appeared in Hanasaki and Yamamoto. 2010)

11.1 Preprocessing

1. Change directory to lnd/dat, and execute,

```
% createcp5 0.0 uniform.0.0.cp5
```

2. Change directory to dam, and execute,

```
% mkdir ini
% cd ini
% createcp5 0.0 uniform.0.0.cp5
```

3. Change directory to crp, and execute,

```
% mkdir ini
% cd ini
% createcp5 0.0 uniform.0.0.cp5
```

4. Download crp-org-SWIM.tar.gz. Make a directory crp/org and put the file in the directory, and uncompress it.

Chapter 12 Environmental Water Module

Environmental Water Module

12.3 Preprocessing

1. Change directory riv/out/riv_out_.
2. Make monthly files of river discharge as follows.

```
% mon2yearcp5 ./K10oLR__.cp5DY 1981 1981 ./K10oLR__.cp5MO
% mon2yearcp5 ./K10dLR__.cp5DY 1981 1981 ./K10dLR__.cp5MO
```

12.4 Main process

1. Change directory riv/pst.
2. Edit and execute calc_envout.sh.

```
PRJ=K10d     # or K10o
RUN=LR__
YEARMIN=1981
YEARMAX=1981
L=5040
XY="60 84"
LONLAT="97 102 13 20"
L2X=../../map/dat/l2x_l2y_/l2x.cp5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.cp5.txt
SUF=.cp5
MAP=.K10S
```

Chapter 13 Coupled Model

13.3 Preprocessing

1. Change directory cpl/pre.
2. Edit and execute prep.sh.

```
L=5040
XY="60 84"
LONLAT="97 102 13 20"
L2X=../../map/dat/l2x_l2y_/l2x.cp5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.cp5.txt
SUF=.cp5
MAP=.K10S
```

13.4 Main process

1. Download dam-bin-M12.tar.gz. Put it to dam/bin, and uncompress it. This results in the creation of a sub directory dam-bin-M12. Move the all files in dam/bin/dam-bin-M12 to dam/bin by

```
% mv dam-bin-M12/* .
```

   Because the files contain Fortran source code files, compile again by

```
% make clean
% make all
```

2. Download cpl-bin-M12.tar.gz. Put it to cpl/bin and uncompress it. This results in the creation of a sub directory cpl-bin-M12. Move the all files in cpl/bin/cpl-bin-M12 to cpl/bin by

```
% mv cpl-bin-M12/* .
```

   Because the files contain Fortran source code files, compile again by

```
% make clean
% make all
```

3. Edit and execute main_M12.sh. To run reservoir simulation, change the following four variables referring to Table 13-1.

```
PRJ
RUN
OPTDAMRLS
DAMSTOMIN
```

Table 13-1 Settings for reservoir simulation

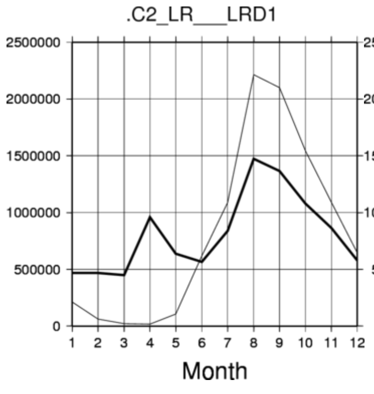
Simulation	PRJ	RUN	OPTDAMRLS	DAMSTOMIN
High	K10o	LRDh	M12plus3	0.75
Mid	K10o	LRDm	M12plus3	0.50
Low	K10o	LRDl	M12	0.25
Low until May	K10o	LRD1	M12flat1	0.25
Low until June	K10o	LRD2	M12flat2	0.25
Low until July	K10o	LRD3	M12flat3	0.25

13.5 Post processing

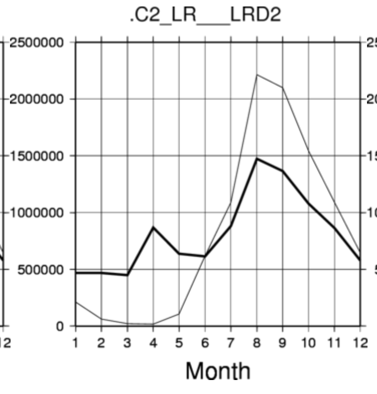
1. Change directory cpl/pst
2. Edit and execute list_watbal.sh.
3. Download cpl-pst-M12.tar.gz. Put it to cpl/pst and uncompress it. This results in the creation of a sub directory cpl-pst-M12. Move the all files in cpl/pst/cpl-pst-M12 to cpl/pst by

```
% mv cpl-pst-M12/* .
```

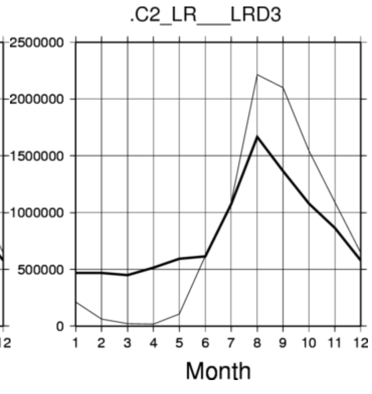
4. Edit and execute draw_graph.sh. Now you will have an image file similar to Figure 13-1 (a)-(f).



(a)



(b)



(c)

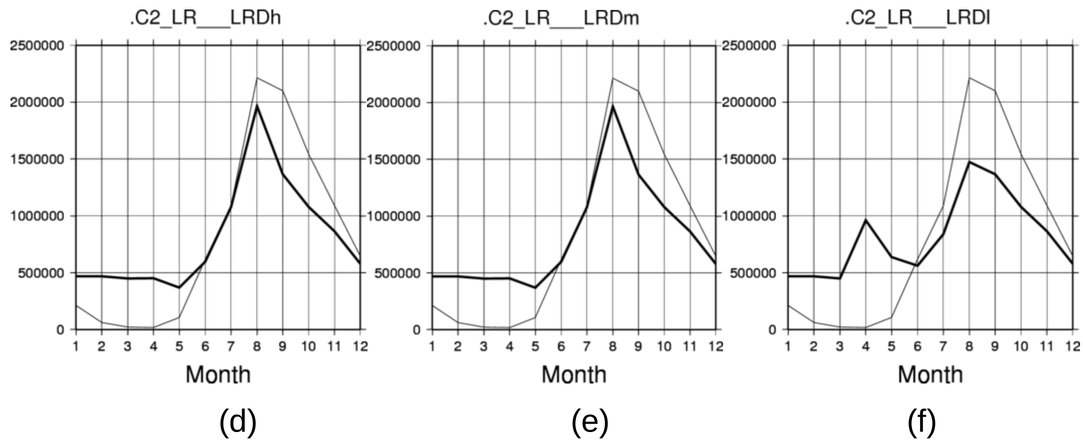


Figure 13-1 Reservoir Simulation Hydrograph

13.6 Theory in brief

Reservoir operation model is a model to estimate release from the reservoir.

In this simulation, we set release from reservoirs from historical mean. Figure 13-2 shows the historical mean monthly release of the Bhumibol Reservoir. From January to April, the release is high, while low in the remaining months. We found the historical mean release from January 1st to April 30th was 234 m^3/s, and that from May 1st to December 31st was 107 m^3/s. Because the reservoir operation model is implemented to the H08, and the inflow to the modeled reservoir is biased, we needed to correct the release. We noticed that observed mean inflow is 157m^3/s, while simulated inflow is 186m3/s. Release needs further correction. In reality, the released is less than inflow, because of evaporation loss from reservoirs' surface. In the case of the Bhumibol Reservoir, the release to inflow ratio is 0.95. Finally, taking above into account, we set release for dry and wet season at 292 and 133 $m^3 s^{-1}$ respectively.

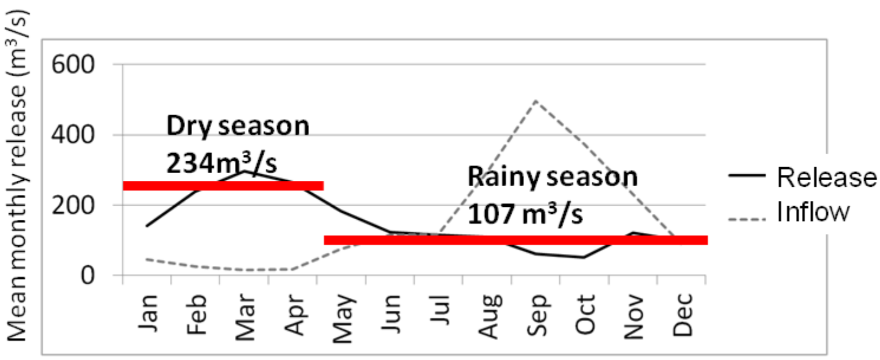


Figure 13-2 Historical mean monthly release of the Bhumibol Reservoir

Table 13-2 Release and inflow of two reservoirs.

	Bhumibol	Sirikit
Observed release (dry) [m^3s^{-1}]	234	225
Observed release (wet) [m^3s^{-1}]	107	130
Observed inflow [m^3s^{-1}]	157	172
Simulated inflow [m^3s^{-1}]	186	105
Observed release/inflow	0.95	0.94
Release for dry season	234*186/157*0.95=292	225*105/172*0.94=146
Release for wet season	107*186/157*0.95=133	130*105/172*0.94=84
Annual release	(292*4+133*8)/12=186	(146*4+84*8)/12=105

If a reservoir's storage was always sufficient and its capacity was infinite, the reservoir could release constantly. However, reservoirs in reality can be depleted and filled. In these cases, release is forced to be decreased and increased.
In this model, when the storage is depleted, the release is equal to inflow. When the storage is larger than the upper curve, the overflowing water is added to release.
The upper curve was derived from the actual reservoir operating rule of the Bhumibol and Sirikit Reservoirs.

Figure 13-3 shows the actual upper and lower curve of the Bhumibol Reservoir. Open circles are old curves, filled circles are new curves, and thick solid line is actual storage of early 2012. We focused on the lowest point of each curves (end of July for new/old curves, and end of April for 2012 curve), and the storage of each point is shown in Table 13-3. The upper curves were simplified as shown in Figure 13-4.

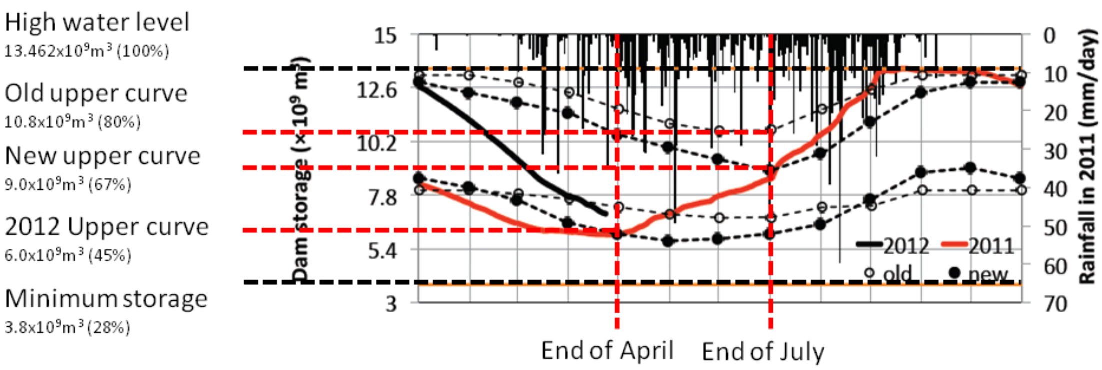


Figure 13-3 Actual upper and lower curve of the Bhumibol Reservoir.

Table 13-3 The minimum level of upper curve

	Bhumibol	Sirikit
Lowest storage in the old upper curve[m^3]	10.8×10^9	7.2×10^9
Lowest storage in the new upper curve[m^3]	9.0×10^9	6.2×10^9
Lowest storage in the 2012 rule curve[m^3]	6.0×10^9	4.3×10^9

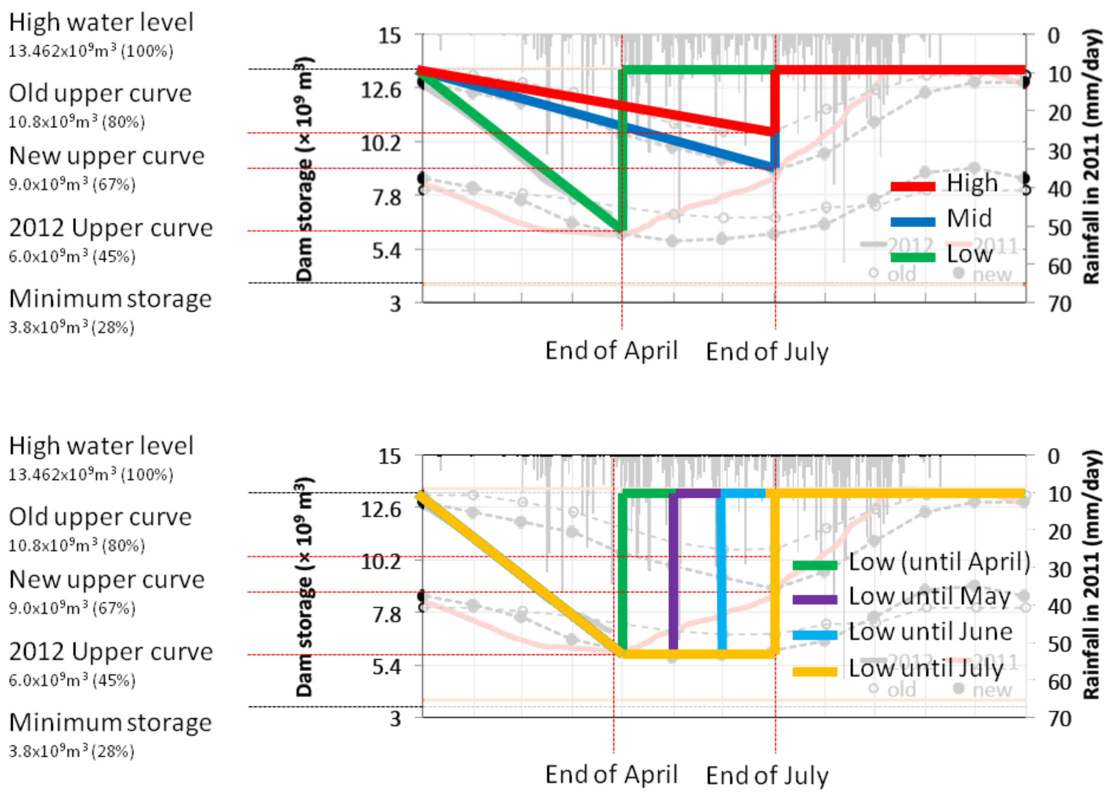


Figure 13-4 Simplified upper curves

Now, let's express the volumes in Table 13-4 as a fraction of reservoir capacity. Table 13-4 shows the High Water Level (maximum storage capacity), minimum storage, and effective storage of two reservoirs respectively. Finally, Table 13-5 shows the results. In this simulation, the fraction of storage to the effective capacity is used (shown in red ink).

Table 13-4 Capacity of reservoirs

	Bhumibol	Sirikit
High Water Level (HWL) [m^3]	13.462×10^9	9.510×10^9
Minimum storage[m^3]	3.8×10^9	2.85×10^9
Effective storage (ES) [m^3]	$13.462\times10^9-3.8\times10^9$ $=9.662\times10^9$	$9.510\times10^9-2.85\times10^9$ $=6.660\times10^9$

Table 13-5 Fraction of storage

	Bhumibol	Sirikit
Lowest storage in the old upper curve as percentage of HWL	10.8/13.462=0.80 80% of HWL	7.2/9.510=0.76 76% of HWL
Lowest storage in the new upper curve as percentage of HWL	9.0/13.462=0.67 67% of HWL	6.2/9.510=0.65 65% of HWL
Lowest storage in the 2012 rule curve as percentage of HWL	6.0/13.462=0.45 45% of HWL	4.3/9.510=0.45 45% of HWL
Lowest storage in the old upper curve as percentage of ES	7.0/9.662=0.72 (~75% of ES)	4.35/6.666=0.65 (~75% of ES)
Lowest storage in the new upper curve as percentage of ES	5.2/9.662=0.53 (~50% of ES)	3.35/6.666=0.50 (~50% of ES)
Lowest storage in the 2012 rule curve as percentage of ES	2.2/9.662=0.23 (~25% of ES)	1.45/6.666=0.22 (~25% of ES)

Chapter 14 Applied Uses Applied Uses

14.1 Global warming

1. Obtain the results of global warming numerical experiments using a global climate model. They can be obtained relatively easily using the global water resources model input/output server[6]. The current standard method is to obtain 30 years' of future and current data for surface air temperature (tas), precipitation (pr), and downward longwave radiation (rlds). See Table 14-1 for details. You will see a screen like Figure 14-1. You have two options afterwards. First option is to click each URL and download files one by one. Put the all surface air temperature files (e.g. 4882tas2070.tar.gz) to met/dat/Tair____, precipitation files (e.g. 4882pr2070.tar.gz) to Prcp_____, and longwave downward radiation files (e.g. 4882rlds2070.tar.gz) to LWdown__. Second option is to click "Your Personal Site Link", and just remember the URL of this site (e.g. http://h08.nies.go.jp/~ddc/tmp/ddc_data/4872/) and the number appeared in each files (e.g. 4882).
2. Change directory to met/pre. Edit and execute prep _CMIP3_mean.sh to create 30-year averages. This results in downloading all files and outputting mean 30 year data for the A2 scenario in met/dat/Tair____, met/dat/Prcp____, and met/dat/LWdown__.

```
PRJ=m32m,
RUN=a21_
RUNOUT=a213
YEARMIN=2070
YEARMAX=2099
L=5040
OPTWGET=yes
URL=
PID=
OPTGZIP=yes
```

3. Again execute prep _CMIP3_mean.sh for the past (20C3M).

[6] http://h08.nies.go.jp, and log in as user: cmip5, password: CMIP5

```
PRJ=m32m,
RUN=201_
RUNOUT=201_
YEARMIN=1961
YEARMAX=1990
L=5040
OPTWGET=yes
URL=
PID
OPTGZIP=yes
```

4. Edit (Geographical settings) and execute prep _CMIP3_delta.sh to calculate differences between current and future temperature and downward longwave radiation, and calculate rates of change for current and future precipitation . This results in outputting temperature difference in met/dat/Tair__DF, longwave difference in met/dat/LWdownDF, and precipitation change in met/dat/Prcp__RT.

5. Edit and execute prep_RH.sh to calculate relative humidity.

```
PRJ=K10_,
RUN=____,
YEARMIN=1981,
YEARMAX=1981,
L=5040
SUF=.cp5
QAIR=../../met/dat/Qair____/${PRJ}${RUN}${SUF}DY
PSURF=../../met/dat/PSurf___/${PRJ}${RUN}${SUF}DY
TAIR=../../met/dat/Tair____/${PRJ}${RUN}${SUF}DY
RH=../../met/dat/RH______/${PRJ}${RUN}${SUF}DY
```

6. Change directory to lnd/bin, and "Meteorological input" section of edit main.sh. In a standard simulation, humidity is expressed in specific humidity, therefore, QAIR will contain file names, and RH will contain NO. In climate change simulation, humidity is expresses in relative humidity, therefore, QAIR will contain NO and RH will contain file names.

```
QAIR=NO
RH=../../met/dat/RH______/K10______${SUF}DY
```

7. Edit "Climate change input" and "Climate change output" sections of main.sh. Add temperature differences respectively to TCOR, PCOR, and LCOR. Set TAIROUT, RAINFOUT, SNOWFOUT, and LWDOWNOUT, this will give you temperature, precipitation, and downward longwave radiation after shifting/scaling.

```
TCOR=../../met/dat/Tair__DF/m32ma213.binMM
PCOR=../../met/dat/Prcp__RT/m32ma213.binMM
LCOR=../../met/dat/LWdownDF/ m32ma213.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
```

8. Set PRJ in main.sh. In this case, set "mm23" short for MIROC 3.2 medres, A2 scenario, Period 3". Do not change YEARMIN and YEARMAX. The concept of shifting and scaling is add/multiply the difference to the simulation for the past. The output files will be named suc ahs "mm23LR__19860101.one", and these are the simulation results for 2070-2099.

```
PRJ=mm23
RUN=LR__
YEARMIN=1981
YEARMAX=1981
```

9. Execute main.sh. You can run crp/bin/main.sh, cpl/bin/main.sh similariy.
10. Change directory cpl/pst, and edit list_watbal.sh. Do not forget to change rainfall and snowfall to the values set with RAINFOUT and SNOWFOUT. Otherwise water balance does not close.

```
PRJ=mm23
RUN=LR__
PRJMET=mm23
RUNMET=LR__
DIRRAINF=../../lnd/out/Rainfout
DIRSNOWF=../../lnd/out/Snowfout
```

Table 14-1 Data to retrieve

Options	Settings
Dataset	CMIP3
Model	MIROC3.2 medres (m32m)
Scenarios	A2 for first time, and 20C3M for second time
Year:	2070-2099 for A2, 1961-1990 for 20C3M
Ensemble run	1
Variable	pr, tas, rlds
Temporal resolution	Monthly
Domain	97, 102, 13, 20
Spatial resolution	60, 84
Meridional sequence	North to South
File type	Plain binary (little endian) with short name
Compress	Yes

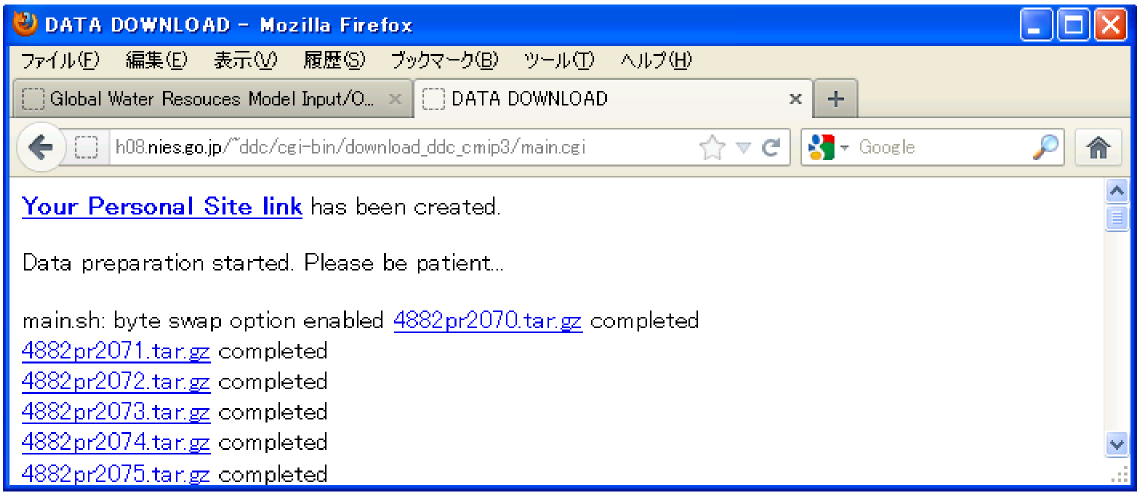


Figure 14-1 Screen shot

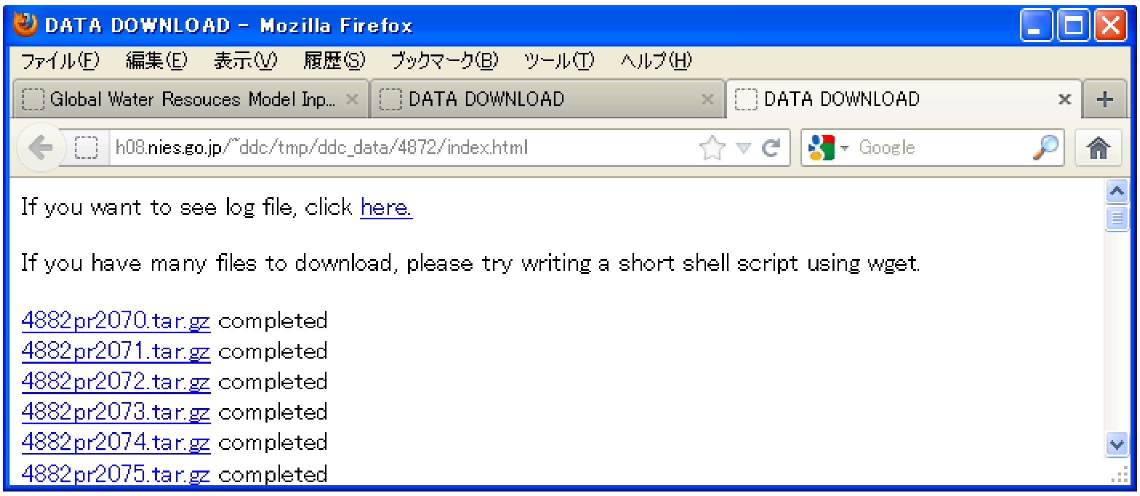


Figure 14-2 Screen shot

Appendix A
Global Warming Simulation Using W13

A.1 Preprocessing

1. Download met-pre-W13.tar.gz from the H08 file server, uncompress it, and put the file “prep_W13.sh” to met/pre.
2. Download mir5.tar.gz from the H08 file server and put it to met/org/W13/v1.0. If you don’t have met/org/W13/v1.0, make a new directory.
3. Uncompress mir5.tar.gz as follows.

```
% cd ${DIRH08}/met/org/W13/v1.0
% gunzip mir5.tar.gz
% tar xf mir5.tar
```

4. Change directory met/pre.
5. Edit and execute prep_W13.sh. Now you will have global warming metrological data sets prepared by Dr. Satoshi Watanabe.
6. If you don’t have met/dat/Snowf___, then make a new directory.
7. Change directory met/dat/Snowf___ and make binary file as follows.

```
% createcp5 0.0 dummy.0.0.cp5
```

8. Download map-org-W13.tar.gz from the H08 file server and put it to map/org. Then uncompress it.
9. Download map-pre-W13.tar.gz from the H08 file server, uncompress it, and put the file “prep_lnd_W13.sh” to map/pre.
10. Change directory map/pre and execute prep_lnd_W13.sh
11. Change directory map/bin and execute main_riv.sh.

```
MAP=.W13
```

A.2 Main process

This paragraph only shows how to execute lnd/bin/main.sh with W13. If you wish to execute riv/bin/main.sh, crp/bin/main.sh, and cpl/bin/main_M12.sh, refer to previous sections and edit arguments in the shell scripts.

1. Change directory lnd/pre
2. Edit and execute prep.sh. Do not forget to change MAP=.W13.
3. Change directory lnd/bin.
4. Edit and execute main.sh.

```
PRJ=mi58
RUN=LR__
YEARMIN=2080
YEARMAX=2080
SECINT=86400
LDBG=3098     # C2: Nakhon Sawan
SUF=.cp5
MAP=.W13
WIND=../../met/dat/Wind____/mi58____${SUF}DY
RAINF=../../met/dat/Rainf___/mi58____${SUF}DY
SNOWF=../../met/dat/Snowf___/dummy.0.0${SUF}FX
TAIR=../../met/dat/Tair____/mi58____${SUF}DY
QAIR=../../met/dat/Qair____/mi58____${SUF}DY
RH=NO
PSURF=../../met/dat/PSurf___/mi58____${SUF}DY
SWDOWN=../../met/dat/SWdown__/mi58____${SUF}DY
LWDOWN=../../met/dat/LWdown__/mi58____${SUF}DY
TCOR=NO
PCOR=NO
LCOR=NO
TAIROUT=NO
RAINFOUT=NO
SNOWFOUT=NO
LWDOWNOUT=NO
BALBEDO=../../met/dat/Albedo__/mi58____${SUF}MO
```

A.3 Postprocess

1. Change directory met/dat/Rainf___.
2. Make yearly data as follows.

```
% mon2yearcp5 ./mi58____.cp5DY 2080 2080 ./mi58____.cp5MO
```

3. Change directory met/dat/Snowf___.
4. Make a dummy binary file as follows.

```
% createcp5 0.0 mi58____20800000.cp5
```

5. Change directory cpl/pst.
6. Edit and execute list_watbal.sh.

```
PRJ=mi58
RUN=LR__
PRJMET=mi58
RUNMET=____
YEAR=2080
YEARINI=2079
YEAREND=2080
MAP=.W13
DIRRAINF=../../met/dat/Rainf___
DIRSNOWF=../../met/dat/Snowf___
```

Appendix B
Near real time Simulation

B.1 Preprocessing of the SRTM elevation data

1. Download two files of 30 arc-second elevation data (E060N40.DEM and E100N40.DEM) from SRTM website[7] and put them to map/org/SRTM.
2. Download map-pre-SRTM.tar.gz from the H08 file server. Uncompress it and put the file “prep_map_SRTM.sh” to map/pre.
3. Edit and execute prep_SRTM.sh.

B.2 Download the TMD meteorological data

1. Prepare a Windows PC with MS Excel.
2. Make an empty directory named “TMD” at Desktop.
3. Open a web browser and visit TMD website[8]. Download daily meteorological data for the entire year of 2012 (2012/01/01 – 2012/01/31) in MS Excel format for 40 stations shown in Table B1 and Figure B1, and save them to the folder “TMD”. Change the name of Excel file as “*stationID_year*.xls”. For example, if you downloaded data of station ID 3 for the year of 2012, the file name should be 3_2012.xls.
4. Download TMDmacro_20130823.xls or later from the H08 file server, and put it to the directory “TMD”
5. Open TMDmacro_20130823.xls. Enable macros.
6. Execute the macro "Macro_ver_20130823".
   (a) First, select option 1 in "Select Station". This results in processing data for Station 1-37.
   (b) Next, set until when the data exists (month, day, and year). In this case, set 12, 31, and 2012.
   (c) Then, click "ok" of the last pop up window. This results in conversion of Excel files for Stations 1-37. If you look at the directory TMD, you will find 37 text files.
7. Again, execute the macro "Macro_ver_20130823". In this case, select option 2 in "Select Station". This results in processing data for Station 56.
8. Again, execute the macro "Macro_ver_20130823". In this case, select option 3 in "Select Station". This results in processing data for Station 77-78.
9. Confirm that all the Excel files have been converted into ascii files.
10. Transfer the files to met/org/TMD.

[7] Visit http://www2.jpl.nasa.gov/srtm/ and see description carefully. In this example, we used http://dds.cr.usgs.gov/srtm/version2_1/SRTM30/e060n40/e060n40.dem.zip and http://dds.cr.usgs.gov/srtm/version2_1/SRTM30/e100n40/e100n40.dem.zip

[8] http://www.aws-observation.tmd.go.th/web/reports/weather_days.asp

B.3 Preprocessing of the TMD meteorological data

1. Download map-org-TMD.tar.gz from the H08 file server. Change directory map/org and uncompress it.
2. Download met-pre-TMD.tar.gz from the H08 file server. Uncompress it, and put the file prep_TMD.sh to met/pre.
3. Edit and execute prep_TMD.sh.
4. Change directory met/dat/Snowf___ and make a binary file as follows.

```
% createcp5 0.0 dummy.0.0.cp5
```

Table B1 Meteorological stations used in this study.

ID	Region	Station_Name	Longitude	Latitude	Alt.[m]
0001	Northern	Chiang_Mai_Airport	99.06806	18.84333	311
0002	Northern	Tak	99.14000	16.88000	124
0003	Northern	Phitsanulok	100.27581	16.79639	52
0004	Northern	Kampaeng_Phet	99.52667	16.48639	97
0005	Northern	Phichit	100.28889	16.45889	34
0006	Northern	Bhumibol_Dam	99.00222	17.24361	149
0007	Northern	Mae_Sot	98.54194	16.70000	348
0008	Northern	Umphang	98.85972	16.02528	5
0009	Northern	Lamphun	99.03833	18.56694	302
0010	Northern	Doi_Angkhang	99.04528	19.93250	1535
0011	Northern	Mae_Hong_Son	97.97278	19.29972	283
0012	Northern	Mae_Sariang	97.93056	18.17611	230
0013	Northern	Chiang_Rai	99.77917	19.87167	410
0014	Northern	Phayao	99.88361	19.19278	407
0015	Northern	Si_Samrong	99.52667	17.48639	74
0016	Northern	Hang_Chat	99.30139	18.32528	295
0017	Northern	Doi_Musir	98.93528	16.75222	833
0018	Northern	Uttaradit	100.10000	17.61667	63
0019	Northern	Thoen	99.24556	17.63667	232
0020	Northern	Lampang	99.50639	18.27806	248
0021	Central	Lop_Buri	100.62831	14.80000	15
0022	Central	Bua_Chum	101.18719	15.26639	46
0023	Central	Nakon_Sawan	100.13250	15.67194	34
0024	Central	Tak_Fa	100.53031	15.34944	83
0025	Central	Chai_Nat	100.19139	15.15806	48
0026	Central	Ayutthaya	100.72469	14.53444	7
0027	Central	Uthong	99.85917	14.30167	12
0028	Central	Kampaeng_Saen	99.96667	14.01667	4
0029	Central	Chalermphrakiat	100.60581	13.66611	0
0030	Central	Thong_Pha_Phum	98.63306	14.74444	104
0031	Central	Kanchanaburi	99.53611	14.02250	28
0032	Central	Ratcha_Buri	99.81167	13.52833	3
0033	Central	Pratumtani	100.62031	14.11583	8
0037	Central	Bangna	100.56000	13.72639	5
0045	Central	Khao_Kheow	101.39281	14.36222	1259

0034	Eastern	Chachoengsao	101.45189	13.56972	43
0035	Eastern	Chon_Buri	100.98219	13.35556	8
0036	Eastern	Ko_Sichang	100.80281	13.16278	33
0056	North Eastern	Pakchong	101.33189	14.64361	388
0077	North Eastern	Loei_Agrometeorlogical	101.72919	17.30944	270
0078	North Eastern	Loei_Weather	101.73031	17.45250	256

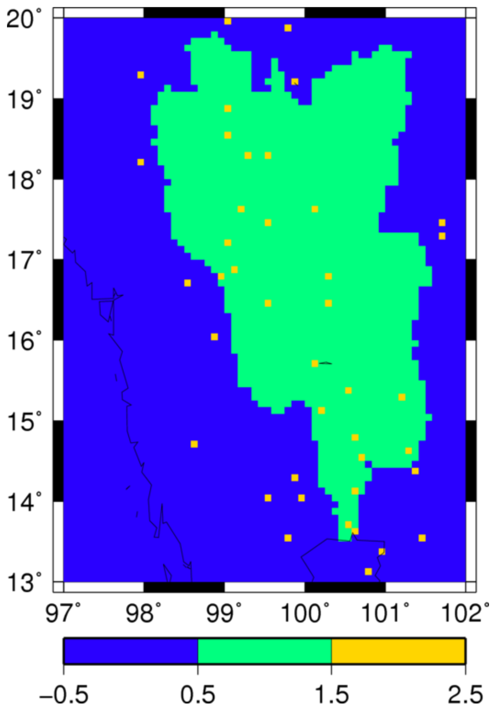


Figure B1 Location of stations

B.4 Preprocessing of the JCDAS meteorological data

1. Change directory to home.
2. Check whether wgrib command is installed.

```
% which wgrib
```

3. If the path to wgrib is not shown to your display, install grads[9]. This is one of the most efficient ways to install wgrib.

```
% yum install grads
```

4. Download JRA-25.gribtab from the H08 file server, and put it to home directory.
5. Add a line to .bashrc file[10]

```
export GRIBTAB=~/JRA-25.gribtab
```

6. Reload .bashrc file

```
% source ~/.bashrc
```

[9] Replace yum with fink, macport, apt-get, and others if necessary.
[10] If you are using csh, add “setenv GRIBTAB ~/JRA-25.gribtab”

7. Change directory to map/pre
8. Edit and execute prep_basmap.sh.

```
L=51200
XY="320 160"
LONLAT="-180 180 -90 90"
SUF=.106
```

9. Change directory to bin
10. Download bin_add.tar.gz from the H08 file server. Uncompress it and put the files to bin. Then, execute,

```
% make htymd2doy
% make htdoy2ymd
% make htrs
```

11. Change directory to met/pre
12. Download met-pre-JCDAS.tar.gz from the H08 file server. Uncompress it, and put the file prep_JCDAS.sh and loop_JCDAS.sh to met/pre.
13. Edit prep_JCDAS.sh.
    1) Obtain user name and password for JRA-25 data from Japan Meteorological Agency[11]
    2) Set user name and password. If your user name is jra12345 and password is abcdefgh then,

```
USER=jra12345
PASS=abcdefgh
```

    3) If you are using big endian, enable IEEE=-ieee. If not, or if you don't understand the meaning of this, just leave as is.
14. Edit loop_JCDAS.sh[12] as shown below, and execute it[13]. Following processes will be completed.
    1) A new directory met/pre/JCDAS has been generated, and the file lists of the remote server (JMA) have been collected.
    2) A new directory met/org/JCDAS has been generated, and the original JCDAS data has been collected.
    3) A new directory met/dat/Tair____ and other directories have been generated, and the H08 meteorological input data has been prepared.

---

[11] http://jra.kishou.go.jp/JRA-25/index_en.html Click the link to "Application".
[12] Option for elevation correction is underway.
[13] If it takes too much time, edit prep_JCDAS.sh as below.
Change line 71:
    Original: `RUNS="anl_mdl fcst_phy2m"`
    Revised: `RUNS="fcst_phy2m"`
Change line 231:
    Original: `VAR in swdown lwdown prcpl prcpc…; do`
    Revised: `VAR in swdown lwdown; do`

```
YEARMIN=2012
MONMIN=01
DAYMIN=01
YEARMAX=2012
MONMAX=12
DAYMAX=31
```

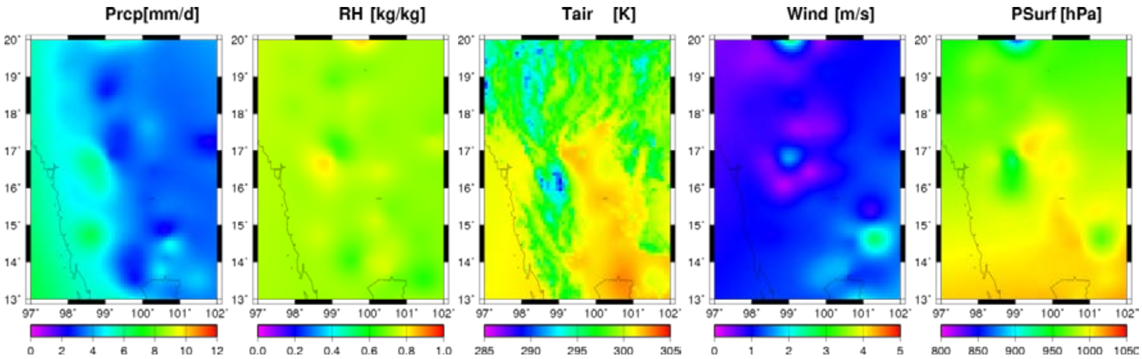


Figure B2 Mean average value of TMD data (2012)

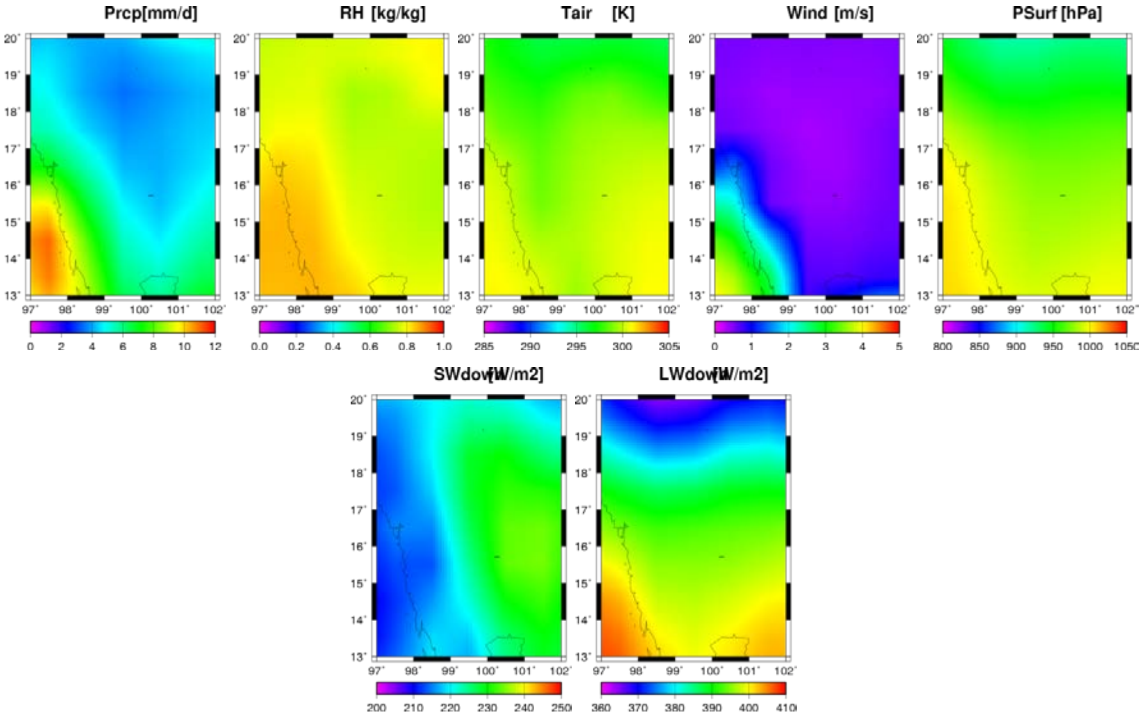


Figure B3 Mean average value of JCDAS data (2012)

With these procedures, you have completed to collect and format near real time input meteorological data. The data flow is shown in Figure B4.

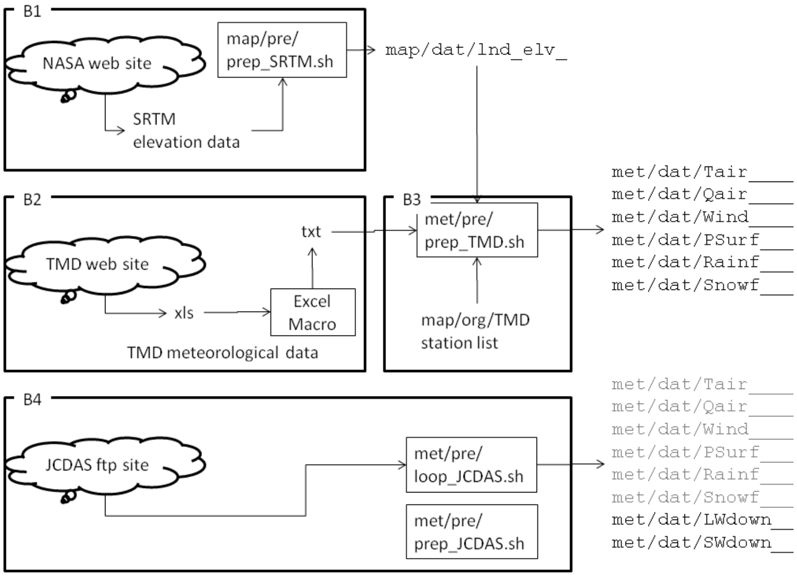


Figure B4 The flow of input meteorological data.

B.5 Main process

This paragraph only shows how to execute lnd/bin/main.sh and riv/bin/main.sh with TMD and JCDAS. In the previous sections, H08 has been run throughout a year. On the contrary, in this section, H08 is run day by day (Figure B5). It means, you can start simulation from any date and end with any date.

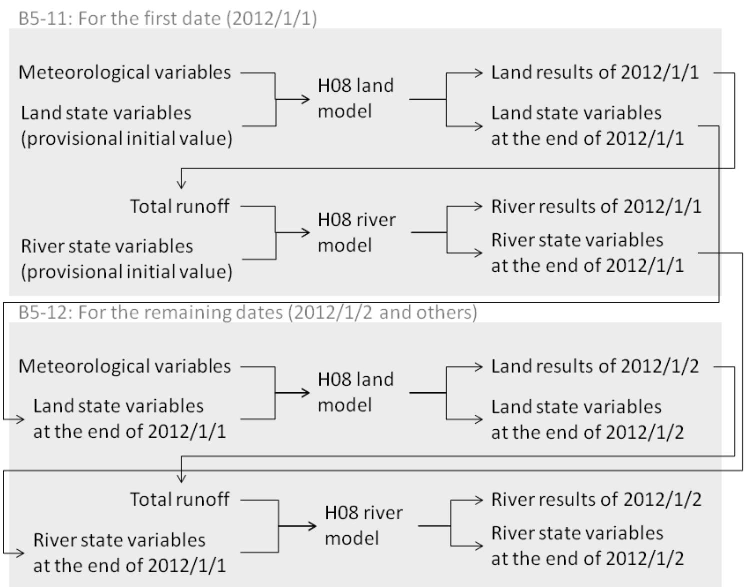


Figure B5 The flow of simulation.

1. Change directory lnd/pre
2. Edit prep.sh as follows and execute it.

```
L=5040
XY="60 84"
L2X=../../map/dat/l2x_l2y_/l2x.cp5.txt
L2Y=../../map/dat/l2x_l2y_/l2y.cp5.txt
LONLAT="97 102 13 20"
SUF=.cp5
MAP=.K10S

V_SOILDEPTH=3.00
V_CD=0.008
V_GAMMA=2.30
V_TAU=120.00
```

3. Change directory lnd/bin.
4. Download lnd-bin-new.tar.gz from the H08 file server. Uncompress it, and put the files to lnd/bin.
5. Edit main_new.f as below and compile it.

```
      parameter (n0l=5040)
```

6. Edit main_new.sh.

```
PRJ=TMDr
RUN=LR__
YEARMIN=2012 # start year, CAUTION overwritten in
YEARMAX=2012 # end year, CAUTION overwritten in
SECINT=86400
LDBG=3098    # C2: Nakhon Sawan
SPNFLG=1
L=5040
SUF=.cp5
MAP=.K10S
```

```
WIND=../../met/dat/Wind____/TMD__gs_${SUF}DY
RAINF=../../met/dat/Rainf___/TMD__gs_${SUF}DY
SNOWF=../../met/dat/Snowf___/dummy.0.0${SUF}FX
TAIR=../../met/dat/Tair____/TMD__gs_${SUF}DY
QAIR=NO
RH=../../met/dat/RH______/TMD__gs_${SUF}DY
PSURF=../../met/dat/PSurf___/TMD__gs_ ${SUF}DY
SWDOWN=../../met/dat/SWdown__/JCDAS___${SUF}DY
LWDOWN=../../met/dat/LWdown__/JCDAS___${SUF}DY
TCOR=NO
PCOR=NO
LCOR=NO
TAIROUT=NO
RAINFOUT=NO
SNOWFOUT=NO
LWDOWNOUT=NO
BALBEDO=../../met/dat/Albedo__/GSW2____${SUF}MM
SOILDEPTH=../../lnd/dat/uniform.3.00${SUF}
CD=../../lnd/dat/uniform.0.008${SUF}
GAMMA=../../lnd/dat/uniform.2.30${SUF}
TAU=../../lnd/dat/uniform.120.00${SUF}
```

7. Change directory riv/bin.
8. Download riv-bin-new.tar.gz from the H08 file server. Uncompress it, and put all the files to riv/bin.
9. Edit main_new.f as below and compile it.

```
      parameter (n0l=5040)
```

10. Edit main_new.sh

```
PRJ=TMDr
RUN=LR__
YEARMIN=2012  # start year, overwritten in
YEARMAX=2012  # end year, overwritten in daybyday mode
SECINT=86400
LDBG=3098      # C2: Nakhon Sawan
SPNFLG=1
L=5040
SUF=.cp5
MAP=.K10S
```

11. Change directory lnd/bin. Edit and execute loop_main_new.sh. This results in simulating the first day of simulation (2012/01/01)

```
YEARMIN=2012
MONMIN=01
DAYMIN=01
YEARMAX=2012
MONMAX=01
DAYMAX=01
OPTINIT=yes
```

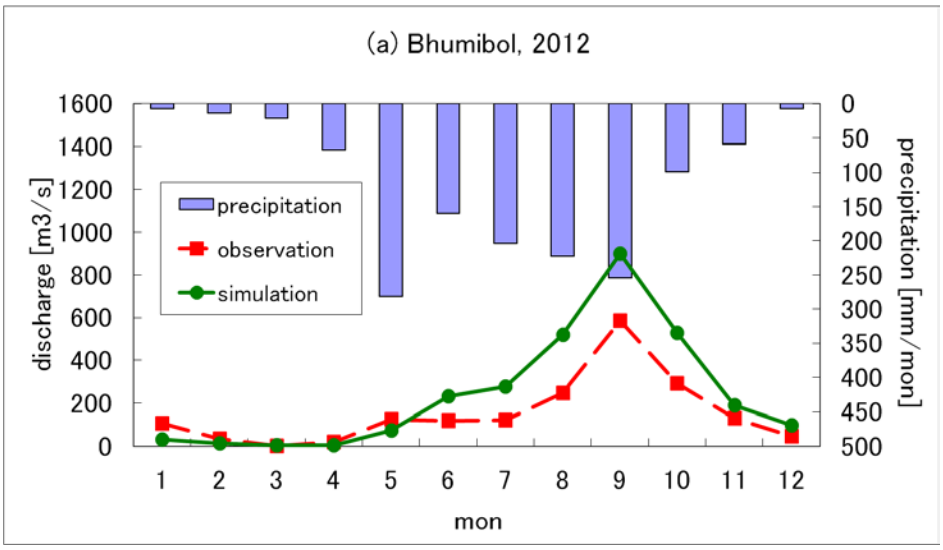
12. Edit and execute loop_main_new.sh. This results in simulating the remaining days of simulation. DO NOT FORGET to change OPTINIT.

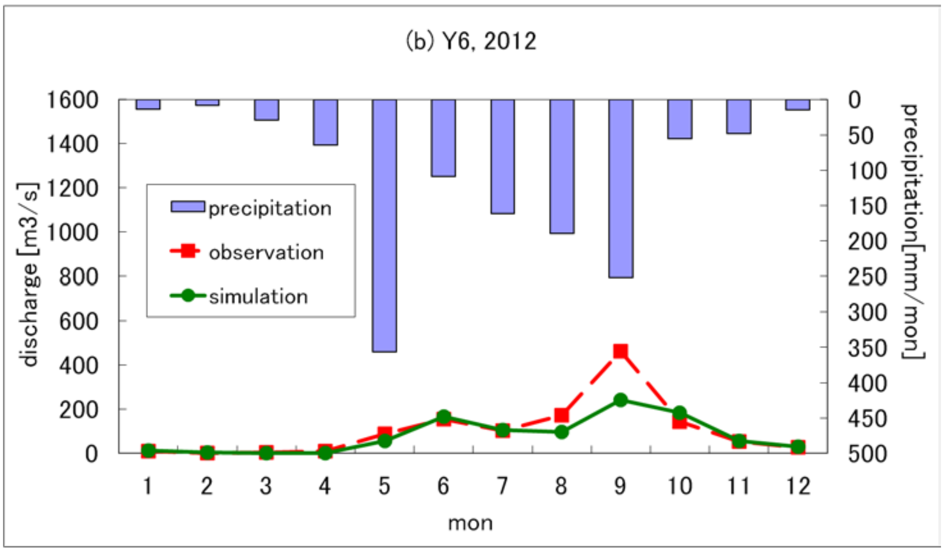
```
YEARMIN=2012
MONMIN=01
DAYMIN=02
YEARMAX=2012
MONMAX=12
DAYMAX=31
OPTINIT=no
```

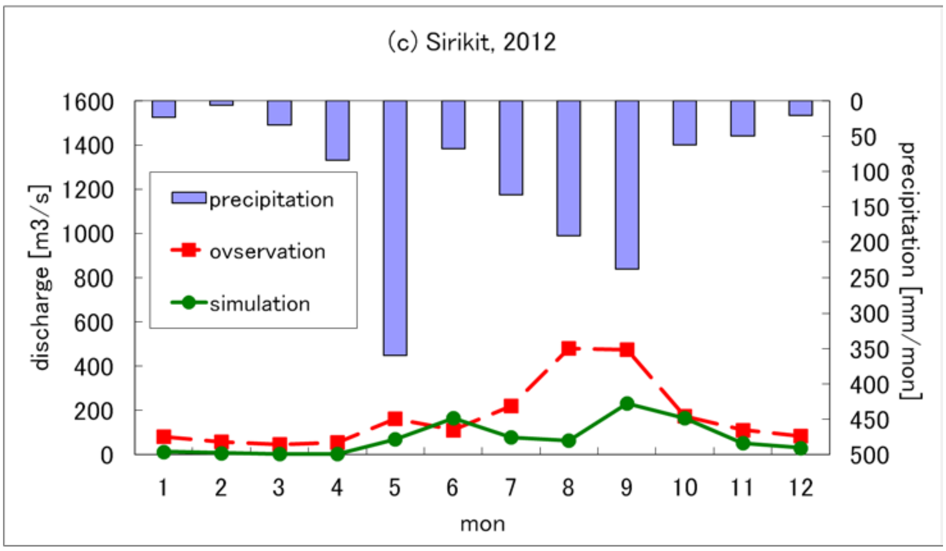
B.6 Postprocess

1. Change directory riv/pst.
2. Download riv-pst-TMD.tar.gz from the H08 file server. Uncompress it , and put the file list_rivout_TMD.sh to riv/pst.
3. Edit list_rivout_TMD.sh as below and execute it. You will obtain the river discharge at C2.

```
PRJ=TMDr
RUN=LR__
#
YEARMIN=2012
MONMIN=1
DAYMAX=1
YEARMAX=2012
MONMAX=12
DAYMAX=31
#
LON=100.11
LAT=15.67
#
DIR=../../riv/out/riv_out_
```


(a) Bhumibol, 2012
discharge [m3/s]
precipitation [mm/mon]
precipitation
observation
simulation
mon
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
450
500
1 2 3 4 5 6 7 8 9 10 11 12


(b) Y6, 2012
discharge [m3/s]
precipitation[mm/mon]
precipitation
observation
simulation
mon
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
450
500
1 2 3 4 5 6 7 8 9 10 11 12


(c) Sirikit, 2012
discharge [m3/s]
precipitation [mm/mon]
precipitation
ovservation
simulation
mon
1600
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
400
450
500
1 2 3 4 5 6 7 8 9 10 11 12

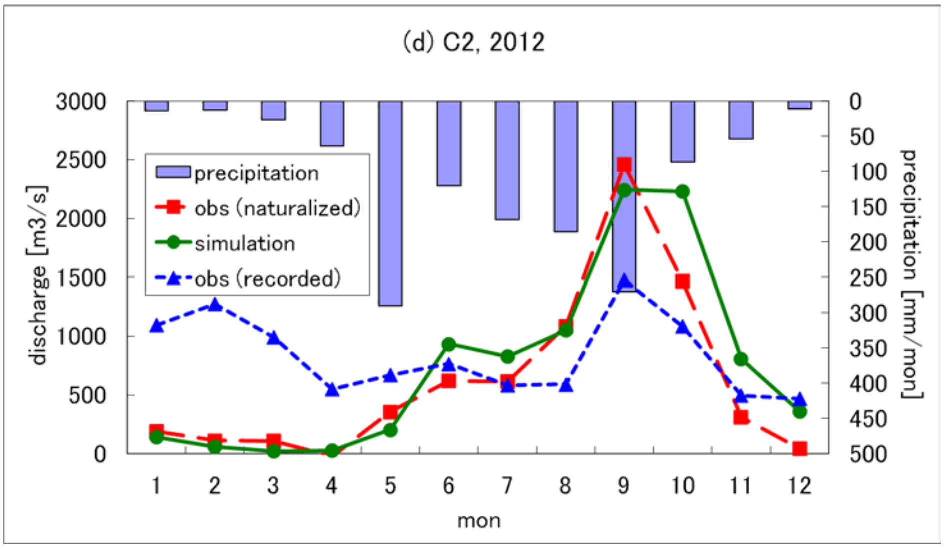


Figure B6 Hydro- and hyetograph of major sub-basins in 2012. Sub-basins at (a) the Bhumibol dam, (b) Y6 Station, (c) the Sirikit dam, and (d) C2 Station.