

User Manual for Distributed Hydrological Model: 1K-DHM-event

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1. Introduction

1K-DHM-event is a distributed hydrologic model based on kinematic wave theory. The model structure is the same as the 1K-FRM-event. 1K-FRM adopts a surface flow momentum equation. Adding surface flow, 1K-DHM includes a surface and subsurface flow momentum equation. From version 2.22, a relation between slope and river channel components are modified to include a river flow routing to all cells. In the version 1 and 2, the topography data is supposed to generate from HydroSHED with 30 second resolution (about 1km resolution). From version 3, any spatial resolution of topography data is accepted and it has an option to set a spatial distribution of the parameter values from data files. The source program is coded using C++ language and it works under Microsoft windows environment and the Linux environment. All program source codes are provided from the home page of Hydrology and Water Resources Research Laboratory at Department of Civil and Earth Resources Engineering, Kyoto University

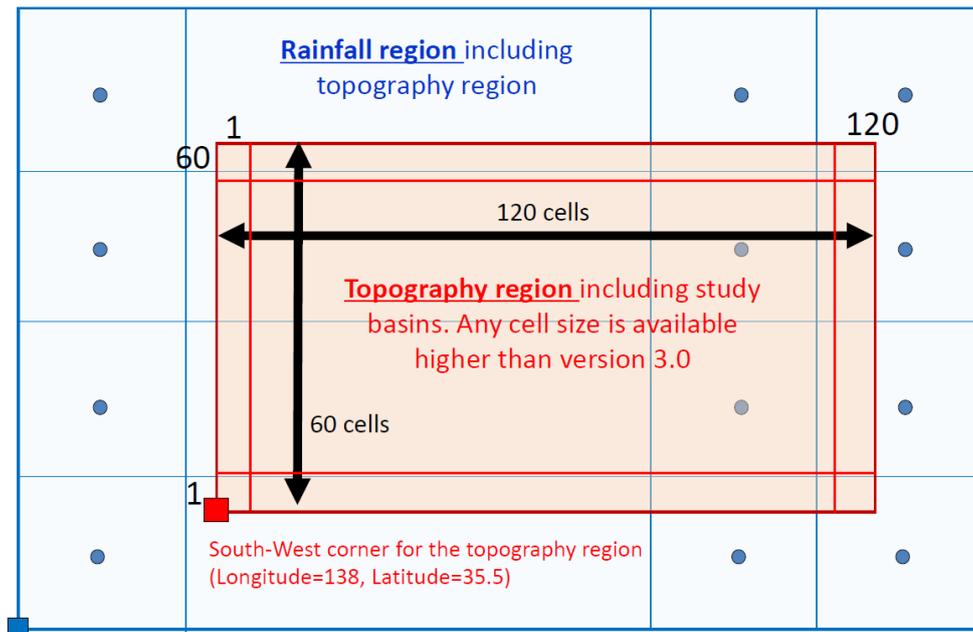
<http://hywr.kuciv.kyoto-u.ac.jp/products/1K-DHM/1K-DHM.html>

To generate topography data for 1K-DHM, two programs are provided:

- Hysroshed2topo: The input data of Hydroshed2topo are DEM and flow direction. The input data of Hydroshed2topo for the Asian region are developed by using HydroSHED <https://hydrosheds.org/> and provided from 1K-DHM web page. The input and output spatial resolution is only 30 seconds.
- AsciiRaster2topo: a program to process any resolution DEM and flow direction data. Accepted input data format is the ESRI Ascii raster format. The data source will be 3, 15 and 30 seconds HydroSHED and 1 second digital elevation model and flow direction J-FlwDir developed by Prof D. Yamazaki at IIS University of Tokyo, <http://hydro.iis.u-tokyo.ac.jp/~yamadai/JapanDir/index.html>.

Forcing data to drive 1K-DHM-event such as precipitation is supposed to be hourly gridded data for version 3 and 10 minutes gridded data for version 4.

In this document, at first, a method to develop topography data for 1K-DHM-event is described. Next, a data format of rainfall input is described. Then, by using the developed, an example of rainfall-runoff simulation using 1K-DHM-event is demonstrated. Finally, several tools to analyze the simulated data is explained. Figure 1 shows entire structure of the coordinate system used for 1K-DHM-event rainfall-runoff simulation.



South-West corner for the rainfall input region
(Longitude=137.8, Latitude=35.325)

Figure 1: Geographic relation of flow routing simulation area and rainfall grid region.

2. Preparation of Topography Data for 1K-DHM-event

2.1 Program to prepare topography data

1) Hydrosched2topo

Hydrosched2topo generate input topography data for 1K-FRM-event, 1K-FRM, 1K-DHM-event and 1K-DHM. The input data of Hydrosched2topo are DEM and flow direction. The input data of Hydrosched2topo for the Asian region are developed by using HydroSHED and provided from 1K-DHM web page. The input and output spatial resolution is only 30 seconds.

2) AsciiRaster2topo

AsciiRaster2topo generate input topography data for 1K-FRM-event, 1K-FRM, 1K-DHM-event and 1K-DHM. The input data of AsciiRaster2topo are DEM and flow direction. Accepted input data format is the ESRI Ascii raster format.

2.2 Input topography data for Hydrosched2topo and AsciiRaster2topo

The topographic data to run 1K-DHM-event are a digital elevation and flow direction data with ESRI ASCII raster format. The data source will be the DEM and flow direction data of 3, 15 and 30 seconds for all globe in HydroSHED <https://hydrosheds.org/>. 1 second data in Japan, J-FlwDir developed by Prof D. Yamazaki at IIS University of Tokyo is also available, <http://hydro.iis.u-tokyo.ac.jp/~yamada/JapanDir/index.html>. From these data, ESRI ASCII raster files for DEM and FlwDir are easily generated by using various software for example ArcGIS. The two files are input data for AsciiRaster2topo. For AsciiRaster2topo, upstream

grid number and drainage area are also input data. These two data is not used for 1K-DHM, so uses may commented out these parts not to use the upstream grid number and drainage area as input data.

Hydroshed2topo and AsciiRaster2topo.cc generate all necessary topographic input files with binary format to run the 1K-DHM-event version 3 and 4 and additional ESRI ASCII files to view by using GIS software such as ArcGIS. First, you need to specify the study area by editing the parameter data file:

- hydroshed2topo/clipArea.dat, or
- asciiRaster2topo/clipArea.dat

This file is a text data file. The study area is determined as a rectangular region by setting longitude and latitude as shown in Figure 2.

- The first row specifies the number of columns for the study region. The value must be an integer value.
- The second row specifies the number of rows for the study region. The value must be an integer value.
- The third row specifies Longitude (degree) of South West (lower left) corner of the study area. The value is a real value.
- The fourth row specifies Latitude (degree) of South West (lower left) corner of the study area. The value is a real value.

The longitude (second) of j-th cell center is set as follows, where Δ is a cell size.

$$\text{longitude} = (\text{int})(\text{SWlon} * 3600) + \Delta * j + \Delta / 2;$$

$$\text{latitude} = (\text{int})(\text{SWlat} * 3600) + \Delta * i + \Delta / 2;$$

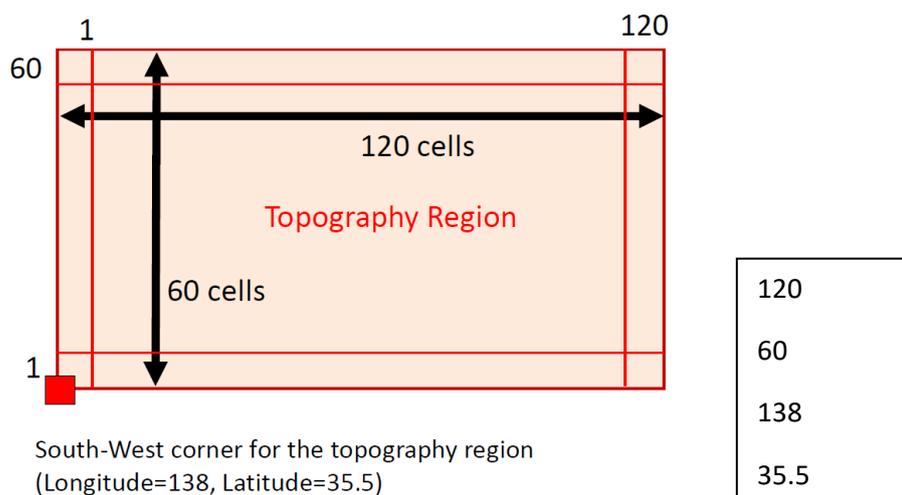


Figure 2: Setting study area (left) and an example of clipArea.dat (right).

2.3 Run the program

Compile and run to generate topographic information for 1K-DHM-event

- Compile hydroshed2topo.cc and run hydroshed2topo.exe, or

- Compile `asciiraster2topo.cc` and run `asciiRaster2topo.exe`.

2.4 Output files

All output files used for the 1K-DHM-event are generated in the folder:

- `hydrosched2topo/output`, or
- `asciiRaster2topo/output`

The binary files for 1K-DHM-event runoff simulation and additional files to view using GIS software are generated. The binary files include data from the South-West grid and lining to East, and then, moving to the North in the next line, which means the South line comes first and then moves to the North. This is a typical GrADS data format. Sample GrADS control files are attached in `asciiRaster2topo` to visualize the data. The additional files to view the generated topography data has ESRI ASCII raster format, which have data from the South-West grid and lining to East, and then, moving to the South in the next line, which means the North line comes first and then moves to the South. The files generated are below:

- **modDem.bin**: This is the corrected (pit removed) elevation information of the study area. The data was written in real 4-byte binary data format.

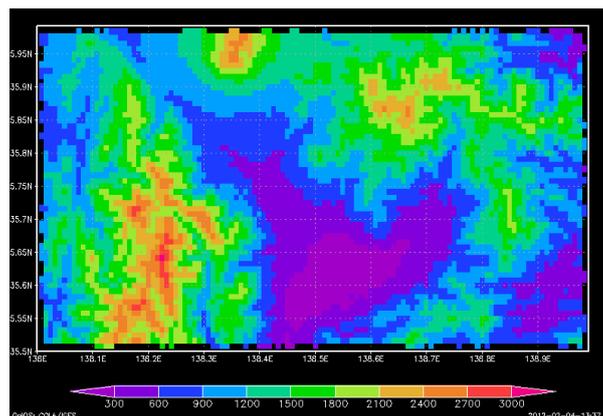


Figure 3: A sample of `modem.bin`.

- **flowDir.bin**: Flow direction information. The direction convention is shown in Figure 3. The data format is integer 4-bite binary.

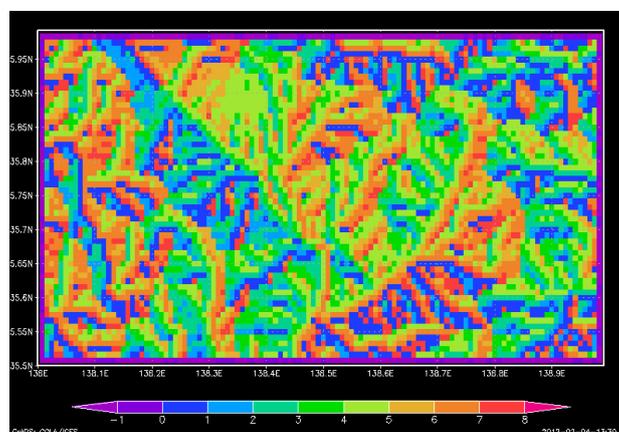


Figure 4: A sample of `flowDir.bin`.

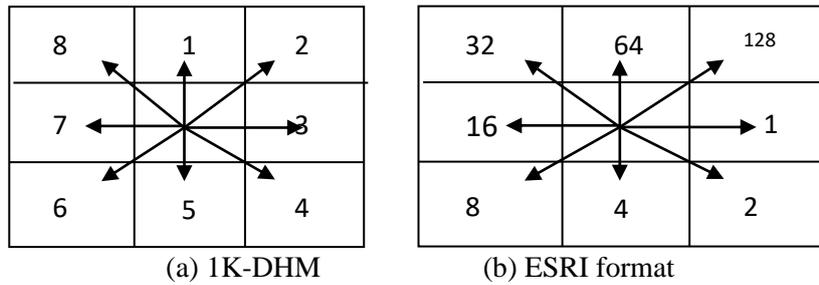


Figure 5: Flow direction specified by the integer value.

- **flowAcc.bin**: Flow accumulation information. The data format is integer 4-bite binary.

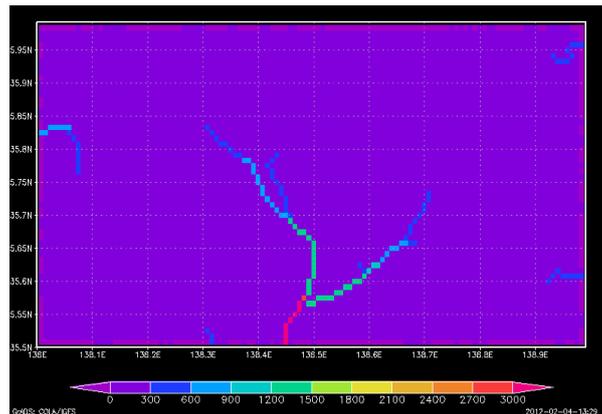


Figure 6: A sample of flowAcc.bin.

- **riverNum.bin**: Each river basin is numbered starting from 1 and then the number is assigned to each grid cell in which of the basin the cell is belongs to. The data format is integer 4-bite binary.

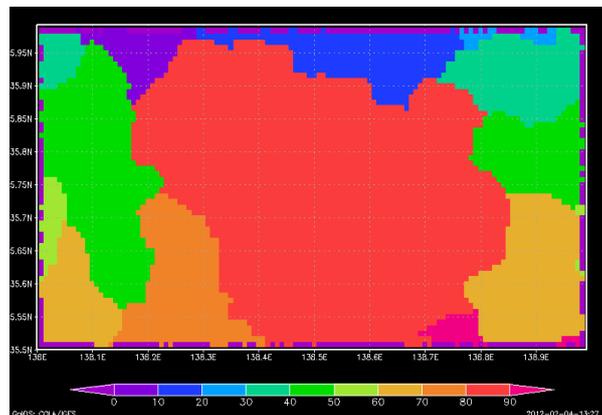


Figure 7: A sample of riverNum.bin.

- **riverNumList.txt**: This is a text file which contains basin information as below:

Column 1: river basin number of the study area,
 Column 2: the basin area (acmulated number of grids).
 Column 3: column number starting from 1 (starting from West),
 Column 4: row number starting from 1 (starting from South),
 Column 5: longitude (second),
 Column 6: latitude (second),

Column 7: longitude (degree), and
Column 8: latitude (degree)

```
1 5 10 59 497085 129555 138.079 35.9875
2 3 14 59 497205 129555 138.113 35.9875
3 4 16 59 497265 129555 138.129 35.9875
4 4 17 59 497295 129555 138.137 35.9875
5 4 18 59 497325 129555 138.146 35.9875
...
```

Figure 8: An example of riverNumList.txt.

To calculate rainfall-runoff simulation for only some selected basins, keep the lines of the selected basins in the riverNumList.txt and delete other lines from this file.

Additional files are also created under the folder

- hydrosGED2topo/output/arcgis, or
- asciiRaster2topo/output/arcgis

These files have the ESRI ASCII file format.

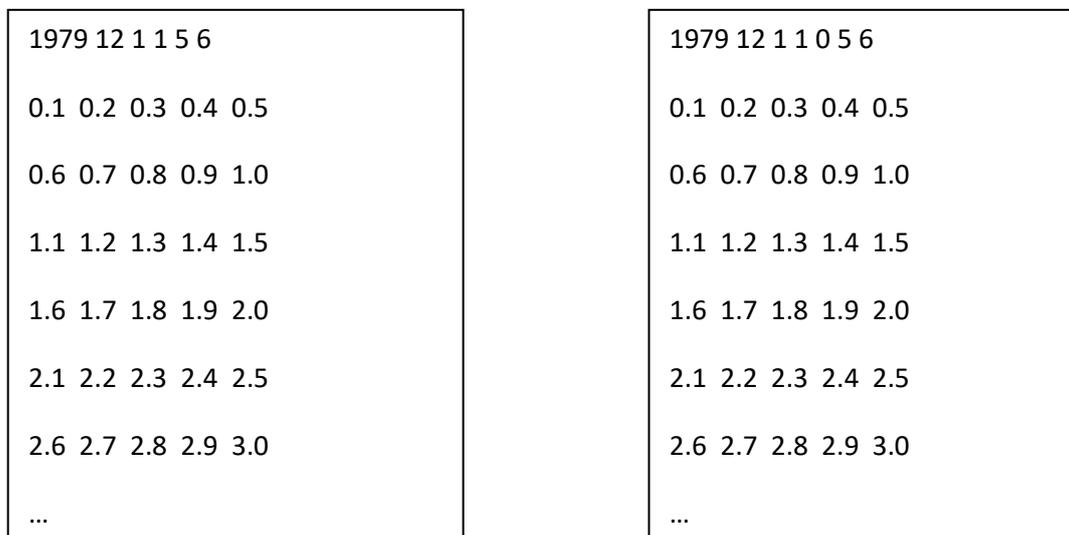
- **cutDem.asc**: The DEM data for the study region. This is the original data clipped for the study region.
- **cutDir.asc**: The DIR data for the study region. This is the original data clipped for the study region.
- **cutUpa.asc**: The upstream drainage area for the study region. This is the original data clipped for the study region. AasciiRaster2topo only.
- **cutUpg.asc**: The grid number of upstream area for the study region. This is the original data clipped for the study region. AasciiRaster2topo only.
- **distance.asc**: The distance from the river mouth.
- **flowAcc.asc**: Flow accumulation value information, which corresponds to **flowAcc.bin**.
- **flowDir.asc**: The Flow Direction data for the study region, which corresponds to **flowDir.bin**.
- **modDem.asc**: The DEM data for the study region. This is the corrected (pit removed) elevation information of the study area, which corresponds to **moDem.bin**.
- **riverNum.asc**: The river basin numbers of the study area, which corresponds to **riverNum.bin**.
- **Col.asc**: The column number of each grid for the study region. This file is used to obtain the exact column number overlapping with other data.
- **Row.asc**: The row number of each grid for the study region. This file is used to obtain the exact row number overlapping with other data.

3. Preparation of Forcing Data (Rainfall data)

A spatially distributed rainfall intensity data is given to 1K-DHM-event. The rainfall file is placed at

1k-dhm-event/input/rain.dat

The name of the file must be “rain.dat” and the file should be placed under “input” folder. An example of rain.dat is shown in Figure 9. The first line of “rain.dat” is Year, Month, Day, Hour, Column Number, and Row Number of spatially gridded rainfall data. From the next line, rainfall intensity values (mm/hr) are stored beginning from the North-West grid and lining to East, then, moving to the South in the next line. Each data is delimited by white space characters (SPACE, TAB, or CR).



(a) example of version 3 for hourly data

(b) example of version 4 for 10minutes data

Figure 9: Part of rain.dat. Left is for 1K-DHM-event version 3 and right is for version 4. For the left example for version 3, the 1st Row is: Year, Month, Day, Hour, Column Number, Row Number. For the right example for version 4, the 1st Row is: Year, Month, Day, Hour, Minute, Column Number, Row Number. From the 2nd to 7th Rows, effective rainfall intensities (5 columns and 6 rows) in mm/hr are stored for the left example and mm/10monutes for the right example.

If the data period is shorter than the simulation time, the rainfall intensity after the given data time is assumed to zero.

The geographic structure is shown in Figure 10. The rainfall intensity data represents the intensity of each grid center. The time interval of the rainfall intensity must be hour for version3 and 10 minutes for version 4. Figure 11 shows the relation between the rainfall-runoff simulation region and rainfall grid region. For runoff simulation, the nearest grid of rainfall intensity is selected.

The grid size of forcing data is set in the parameter setting file for 1K-DHM-event. The grid center of longitude (degree) and latitude (degree) of j-th column and i-th row for input data are set as follows:

```
longitude = ROF_WLON + j*Delta_x; // set longitude
latitude = ROF_SLAT + j*Delta_y; // set latitude
```

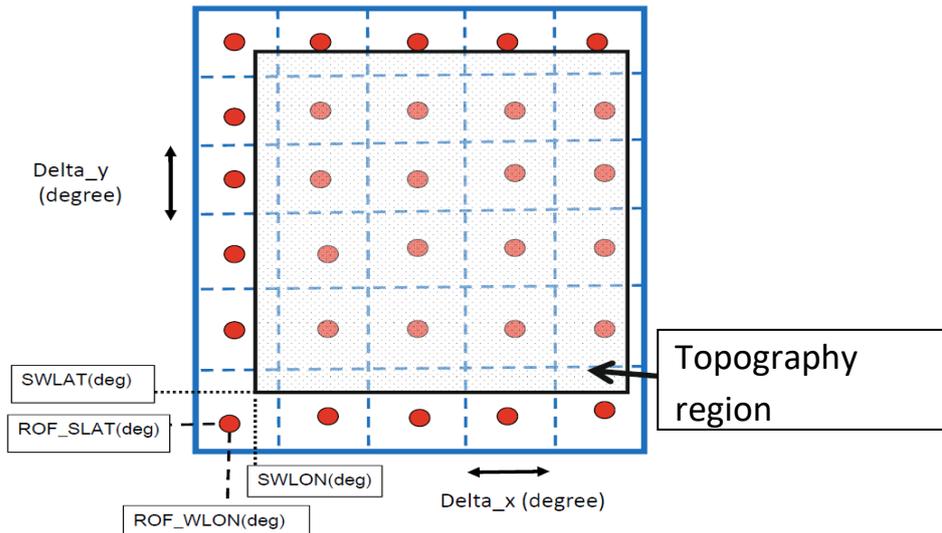


Figure 10: Structure of coordinate of the rainfall grid system.

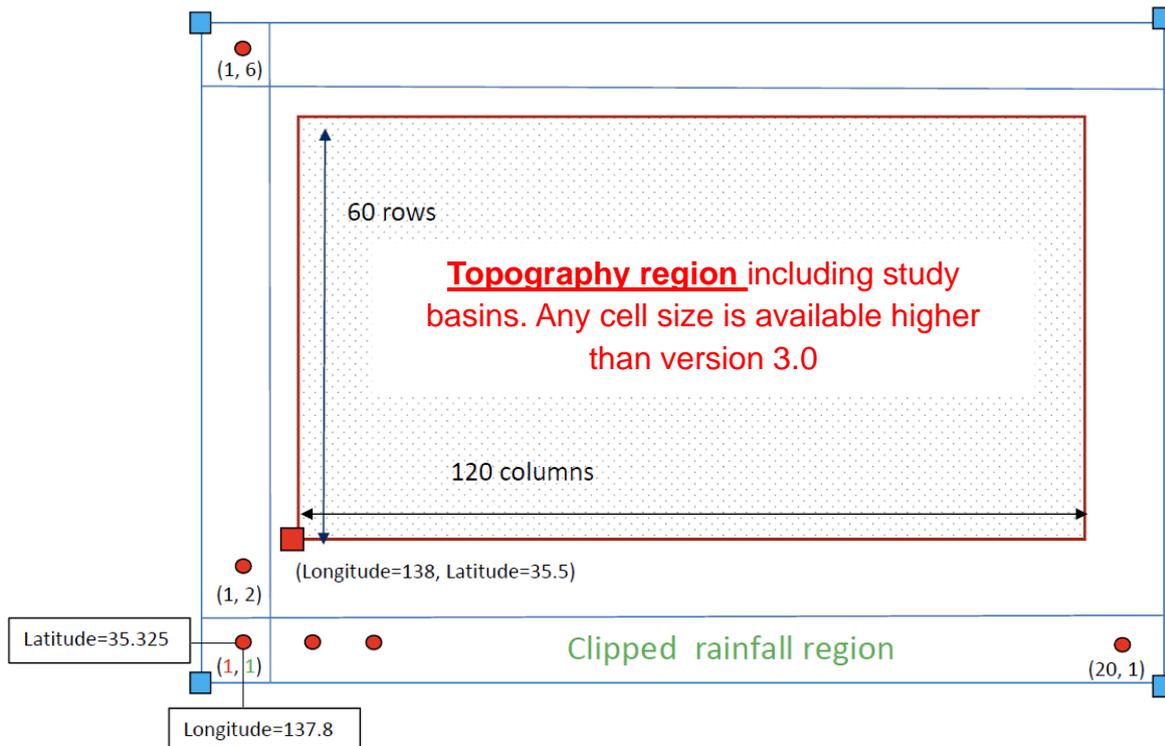


Figure 11: Geographic relation of rainfall-runoff simulation area and rainfall grid region.

Rainfall data is also provided in the binary format with each value being 4-byte floating number. The rainfall data file name is then “rain.bin” and should be placed at

1k-dhm-event/input/rain.bin

The binary data should be arranged from south to north against the above text format. Rainfall data format is switched by changing a parameter “Format of rainfall data” in the “param-dhm-event.dat”.

4. Hydrologic Simulation Using 1K-DHM-event

Figure 11 shows the geographic relation of the rainfall-runoff simulation area and the rainfall grid region for the example data. The procedures for runoff simulation are as follows:

4.1 Setting data

1) Topography data setting:

Copy the topographic information files (above mentioned five files) from “hydroshed2topo/output/” to “1k-dhm-event/topoData/”

2) Rainfall data setting:

Set the rain data and place rainfall data file at “1k-dhm-event/input/rain.dat”. The file name must be “rain.dat”, or “1k-dhm-event/input/rain.bin” when data is prepared in the binary format.

3) Runoff simulation parameter setting:

Edit the runoff simulation parameter file:

“1k-dhm-event/param-event-ver310.dat” for version 3 shown in Figure 12.

“1k-dhm-event/param-event-ver400.dat” for version 4 shown in Figure 13.

by using any text editor. Delimiter of each data is white space characters.

1.0	DEM resolution as second unit.
120	Number of columns of the study area
60	Number of rows of the study area
138.0	Longitude (degree) of South West corner of the study area
35.5	Latitude (degree) of South West corner of the study area.
1	Format of rainfall data (1: text, 2: 4-byte binary)
5	Number of columns of the input forcing data
6	Number of rows in the input forcing data
0.1875	Input data grid size of x-direction (degree)
0.1875	Input data grid size of y-direction (degree)
137.8	Longitude of the center of the Southwest corner of input data (degree)
35.325	Latitude of the center of the Southwest corner of input data (degree)
4	Simulation duration (days)
10	simulation time step (sec)
5	number of spatial divisions
0.65	$0.5 < \theta \leq 1.0$
0.5	Manning's roughness coefficient for slope (m-s unit)
0.0046	Hydraulic conductivity (m/s)
0.3440	Depth of capillary and non-capillary soil layers (m)
0.2875	Depth of capillary soil layers (m)
6.3486	Exponent constant of unsaturated hydraulic conductivity (-)
0.03	Manning's roughness coefficient for river (m-s unit)
0	Grid accumulated number to differentiate slope and river (-). If the value is zero, river routing is included to all grids. If the value is 10, the grids with the accumulated number is less than 10 do not include river routing.
15.0	Slope length (m)
0.0001	Initial runoff height (mm/hr). Zero and negative values are not allowed.

Figure 12: An example of param-event-ver310.dat.

1.0	DEM resolution as second unit.
120	Number of columns of the study area
60	Number of rows of the study area
138.0	Longitude (degree) of South West corner of the study area
35.5	Latitude (degree) of South West corner of the study area.
1	Format of rainfall data (1: text, 2: 4-byte binary)
10	Rainfall time interval (minutes) ←only version 4
5	Number of columns of the input forcing data
6	Number of rows in the input forcing data
0.1875	Input data grid size of x-direction (degree)
0.1875	Input data grid size of y-direction (degree)
137.8	Longitude of the center of the Southwest corner of input data (degree)
35.325	Latitude of the center of the Southwest corner of input data (degree)
4	Simulation duration (days)
10	simulation time step (sec)
5	number of spatial divisions
0.65	$0.5 < \theta \leq 1.0$
0.5	Manning's roughness coefficient for slope (m-s unit)
0.0046	Hydraulic conductivity (m/s)
0.3440	Depth of capillary and non-capillary soil layers (m)
0.2875	Depth of capillary soil layers (m)
6.3486	Exponent constant of unsaturated hydraulic conductivity (-)
0.03	Manning's roughness coefficient for river (m-s unit)
0	Grid accumulated number to differentiate slope and river (-). If the value is zero, river routing is included to all grids. If the value is 10, the grids with the accumulated number is less than 10 do not include river routing.
15.0	Slope length (m)
0.0001	Initial runoff height (mm/hr). Zero and negative values are not allowed.

Figure 13: An example of param-event-ver400.dat.

The parameter values to set in param-event-ver400.dat are as follows:

- The 1st row defines the resolution of topography grid in second unit.
- From the 2nd row to 5th row, the parameters of the study region are specified:

```
int Col=120           // number of columns for study area.
```

```

int Row=60 // number of rows for study area.
double SWLON=135.0 // Longitude (degree) of north west corner of the study area.
double SWLAT=34.0 // Latitude (degree) of north west corner of the study area.

```

- From 6th row to 13th row, the parameters of the rainfall data is specified:

```

int ROFdata_type = 1 // Format of input rainfall data (1: text, 2: 4-byte binary)
int ROFtime_step = 10 // Rainfall time step (min). This line is only for version 4.
int ROFnum_col = 5 // Number of columns of input rainfall data
int ROFnum_row = 6 // Number of rows of input rainfall data
double Delta_x = 0.1875 // Input data grid size of x-direction (degree)
double Delta_y = 0.1875 // Input data grid size of y-direction (degree)
double ROF_WLON = 135.0 // Longitude of the center of the Southwest corner of
// Input data (degree)
double ROF_SLAT = 35.0 // Latitude of the center of the Southwest corner of
// input data (degree)

```

- The 14th row is a parameter to determine the simulation term.

```

int Ndays = 4 // Simulation duration (days)

```

- From 15th row to 17th row, the parameters for the finite difference condition are specified. Usually, you do not need to change these parameter values.

```

int Time_Step = 10 // Simulation time step (sec)
int Nspace = 5 // Number of spatial divisions
double Theta = 0.65 // weight value 0.5 < theta <= 1.0

```

- From 18th row to 25th row, the parameters for the kinematic wave model are specified.

```

double Man_slope = 0.5 // Manning's roughness coefficient for slope (m-s)
double Ka = 0.0046 // Hydraulic conductivity (m/s)
double Da = 0.3440 // Depth of capillary and non-capillary soil layers (m)
double Dm = 0.2875 // Depth of capillary soil layers (m)
double Beta = 6.3486 // Exponent constant of unsaturated hydraulic conductivity (-)
double Man_channel = 0.03 // Manning's roughness coefficient for river (m-s)
int Threshold_basin = 0 // Grid accumulated number to differentiate slope and river (-)
double Ls = 500.0 // Slope length (m)

```

To read the parameter values Man_slope, Ka, Da, Dm, Beta, Man_channel and initial runoff height from data files, negative value such as -999 is set. An example of Ka is given in Figure 14. The file format is ESRI Ascii Raster format. The parameter data should be arranged from North to South and the region should be completely the same as the DEM data. The files must be placed under “paramData” folder and the names is fixed as below:

```

Man_slope param_dist_Ns.dat
Ka param_dist_Ka.dat
Da param_dist_Da.dat

```

Dm param_dist_Dm.dat
 Beta param_dist_Beta.dat
 Man_channel param_dist_Nr.dat
 Initial runoff height param_dist_ROFinitial.dat

Grid accumulated number is used to differentiate slope and rive. If the value is zero, river routing is included to all grids. If the value is 10, the grids with the accumulated number is less than 10 do not include river routing.

- The 26th row is a parameter to determine the initial condition.
 double initialROF = 0.0001 // Initial runoff height (mm/hr). Zero and negative values are
 // not arrowed.

```
ncols 13
nrows 20
xllcorner 135
yllcorner 34
cellsize 0.000277778
NODATA_value -9999
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
...
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
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0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
0.07 0.07 0.07 0.07 0.06 0.06 0.06 0.06 0.05 0.05 0.05 0.05 0.05
```

Figure 14: An example of param_dist_Ka.dat.

4.2 Rainfall-runoff simulation

Move to the folder “/project/1k-dhm-event” and run

“1k-dhm-event-ver???.exe”

All runoff simulation results are created under the folder:

“1k-dhm-event/output”

The files created are below:

- **discharge10minMean.bin:** The file contains the average 10 minutes flow (m³/sec).
- **discharge10minSnapshot.bin:** The file contains snapshot of 10 minutes flow (m³/sec).
- **dischargeHourlyMean.bin:** The file contains the hourly mean flow (m³/sec).

The data are stored in GRADS binary data format and can be visualized using GRADS (<http://www.iges.org/grads/>). All data arranges from west to east at the South row, then North row. GrADS control file:

- flowAnalysisGradsDaily.ctl
- flowAnalysisGradsHourly.ctl

are attached. To extract hydrographs from the output files, the below program is attached in “output” folder.

- extract10minDischarge-ver???.cc: extracts 10 minutes mean and snapshot time series ascii data from the above binary data.
- extractHourlyMeanDischarge-ver???.cc: extracts hourly mean time series ascii data from the above binary data.
- makeppm10minMeanDischarge-ver???.cc: generate time series of spatial distribution of 10 minutes mean discharge with PPM data format from the above binary data.
- makeppmHourlyMeanDischarge-ver???.cc: generate time series of spatial distribution of hourly mean discharge with PPM data format from the above binary data.

4.3 Additional settings

1) Dam model setting

Default model setting is no dam model. If you need to include dam operation in 1K-DHM, the following dam operation is available.

Standard operation of Japanese dam reservoirs is below:

- Dam inflow I is released when I is smaller than a pre-determined flood discharge Q_f ;
- Flood control starts and release Q_f when inflow discharge I exceeds Q_f ;
- If dam storage volume $S(t)$ reaches the effective total storage S_{SL} , all inflow I is released to avoid overtopping, where $S(t) = S_F(t) + S_s - S_p$ ($S_F(t)$ is storage volume

stored until time t , S_s is initial dam storage volume, and S_p is the volume of preliminary release);

According to the above rules, outflow discharge at time t , $Q(t)$ is summarized as follows;

$$Q(t) = \begin{cases} I(t) & (I(t) < Q_f) \\ Q_f & (I(t) \geq Q_f \text{ and } S(t) < S_{SL}) \\ I(t) & (I(t) \geq Q_f \text{ and } S(t) \geq S_{SL}) \end{cases}$$

When dam storage capacity is not considered, outflow discharge at time t , $Q(t)$ is summarized as follows;

$$Q(t) = \begin{cases} I(t) & (I(t) < Q_f) \\ Q_f & (I(t) \geq Q_f) \end{cases}$$

8								
0	2	70	67	0.0e0	0.0e0	0.0e0	0.0e0	Seta
1	1	60	59	8.4e2	0.0e0	6.0e6	2.0e7	Amagase
2	1	82	44	1.3e3	0.0e0	1.38e7	4.92e7	Takayama
3	1	95	26	4.5e2	0.0e0	1.54e7	2.38e7	Shorenji
4	1	81	20	3.0e2	0.0e0	6.55e6	1.43e7	Murou
5	1	78	38	1.0e2	0.0e0	9.0e6	1.54e7	Nunome
6	1	23	91	1.5e2	0.0e0	1.6e7	5.8e7	Hiyoshi

Figure 15: An example of a dam configuration file.

Dam operation type and associated parameters are defined in a dam configuration file:

- ./input/dam.dat

Detail of the file is as follow:

- 1st line: Number of dams
- From 2nd line: Setting of each dam reservoir
 - 1st column: ID of dam
 - 2nd column: Type of dam operation (0: Read dam outflow data, 1: Standard operation of Japanese dam reservoirs, 2: When dam storage capacity is not considered)
 - 3rd and 4th columns: Row and column number of dam cell
 - 5th column: Dam inflow when dam operation starts
 - 6th column: Volume of preliminary release [m³]
 - 7th column: Average dam storage [m³]
 - 8th column: Effective dam storage [m³]

- 9th column: Name of dam

When reading dam outflow data, please set a time series of dam release in the file named:

- ./input/realDamOutflow/Real[Dam Name].dat

[Dam Name] must be the same as the 9th column of a dam configuration file. A time series should be stated day, hour, and outflow [m³/s] at each line.

When you need new type of dam operation, please add dam setting/operation in the following functions of the source code in C++:

- setDamGrid: setting the grid of dam location,
- calculateDamOutflow: dam operation,
- setDamInitialState: setting of initial state variables, and
- setDamParameter: setting of parameter values

2				
1	38	77	12000	Hodu
2	92	47	1500	Iwakura

Figure 16: An example of a reservoir configuration file.

These functions should be set by users depending on a study catchment.

2) Flood inundation model setting

Default model setting is no flood inundation model. If you need to include flood inundation in 1K-DHM, a linear reservoir model is available. A reservoir configuration file:

- ./input/reservoir.dat

should include the following information:

- 1st line: Number of reservoirs
- From 2nd line: Setting of each dam reservoir
 - 1st column: ID of dam
 - 2rd and 3th columns: Row and column number of dam cell
 - 4th column: A parameter of a linear reservoir model
 - 5th column: Name of dam

4.4 Compile

Linux environment: The executable is created by using the GNU g++ compiler as following command

```
% g++ -o 1k-dhm-event-ver222 1k-dhm-event-ver222.cc cellfunc-event.cc roffunc-  
event.cc
```

For Intel C++ compiler of Linux version

```
% icc -o 1k-dhm-event-ver222 1k-dhm-event-ver222.cc cellfunc-event.cc roffunc-event.cc
```

MS Windows environment: Microsoft Visual Studio 2008 or 2010 with C++ compiler is useful. You can download a free version of Visual C++ Express Edition 2008 or 2010 from Microsoft web site. The solution file *1k-dhm-event.sln* should be created according to the Microsoft Visual Studio to use Visual Studio environment. You can also use the command prompt window of the Microsoft Visual Studio. In this case, after opening the command prompt window, you can compile the program as:

```
% cl 1k-dhm-event-ver222.cc cellfunc-event.cc roffunc-event.cc
```

For Intel C++ compiler of windows version

```
% icl 1k-dhm-event-ver222.cc cellfunc-event.cc roffunc-event.cc
```

5. Output Data Analysis

5.1 Visualization of time and space change of discharge using GRADS

GRADS is a free visualization software mainly used by meteorologists. The software works on Windows and Linux/Unix environment. GRADS is available from <http://www.iges.org/grads/>.

You can use an example of GRADS control files “flowAnalysisGradsDayly.ctl” and “flowAnalysisGradsHourly.ctl” in “/project/misc/gradsControlFiles”. Please see the detail information at the web page. Figure 17 is a spatial distribution of discharge at the study region.

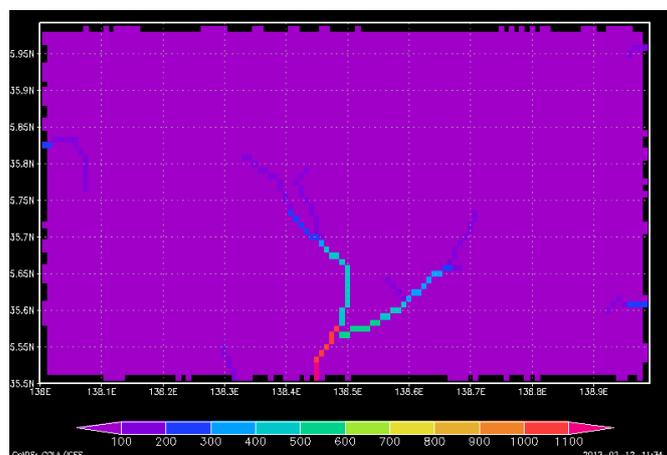


Figure 17: Spatial view of simulated discharge using GrADS.

5.2 Visualization of time and space change of discharge using makeImage.exe and IrfanView

If you do not have GrADS, you can generate PPM format image files and see it using a free image viewer IrfanView. The procedure to see the animation of time and space change of discharge is as follows:

- 1) Run the image generation program makeppm.exe, which is included in 1K-DHM output folder.
 - **makeppmHourlyMeanDischarge-ver???.exe** reads the GrADS format output hourly discharge data **dischargeHourly.bin** generate time series of spatial distribution of hourly mean discharge with PPM data format from the above binary data.
 - **makeppm10minMeanDischarge-ver???.exe** generate time series of spatial distribution of 10 minutes mean discharge with PPM data format from the above binary data.
- 2) Generate PPM format image files under image folder. To run the program,
 - 1-1) Open the folder “1k-dhm-event”
 - 1-2) Click “makeppm.exe”
 - 1-3) Image files are generated under “1k-dhm-event/image/”.
- 3) Install IrfanView. This is a very popular free image viewer. Download the file and follow the instruction. The viewer is installed and you will find the icon on your MS-Windows desktop.
- 4) Click the IrfanView icon and select [File]→[Slideshow]. Then, set the location of PPT image file. You can enjoy the animation.
- 5) Another method to view the animation is to select [File]→[Open], select the image folder and click the first image. Then, select [View]→[Start/Stop automatic viewing]. You can select [View]→[Display option (window mode)] to enlarge the image.

5.3 Time series of discharge data at specific point

The procedures to extract the time series of discharge data at the specific point is as follows:

- 1) Run the time series extraction program extract???.exe. This program reads the GRADS format output data and generates text format time series data under /output.
 - **extract10minDischarge-ver???.exe**: extracts 10 minutes mean and snapshot time series ascii data from the above binary data.
 - **extractHourlyMeanDischarge-ver???.exe**: extracts hourly mean time series ascii data from the above binary data.
- 2) To run the program,
 - 1-1) Open the folder “1k-dhm-event”.
 - 1-2) Click “extract10minDischarge-ver???.exe”.
 - 1-3) You will be asked to input the column and row number to extract the data. To determine the column and row number, it is useful to see the accumulated catchment data “hydrosched2topo/output/flowAcc.asc to examine the discharge with large catchment size. The row and column number begins from the South West corner starting from 1.

- 1-4) The extracted data is generated under “1k-dhm-event\output\Col-Row-discharge.dat”. The first column of the data is time count (hour) and the second column is discharge (m^3/sec).

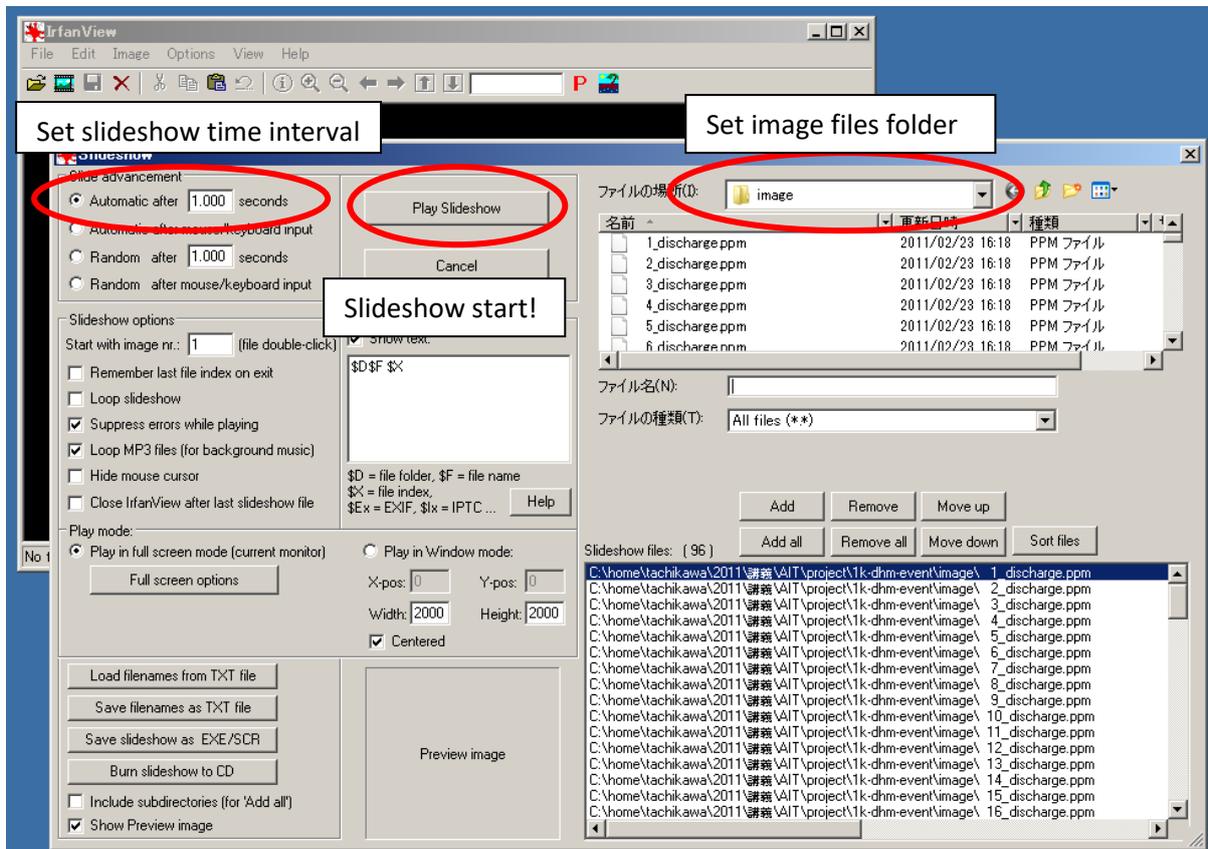


Figure 18: IrfanView Slideshow setting.

1	0.0882515
2	0.653777
3	2.2653
4	7.35936
5	14.4867
6	20.414
7	25.6387
8	32.4114
9	43.8638
10	55.3801
...	

Figure 19: An example of time series discharge data extracted by using extractHourlyMeanDischarge-ver???.exe

- 3) To draw the hydrograph, you can use Excel or GnuPlot (<http://www.gnuplot.info/>).