## Climate by HRU Distribution Module (Updated March 2013)

The Climate by HRU Distribution Module (`climate_hru`), provides a method to input daily time-series climate values, pre-distributed to each HRU. Thus, it is possible to use any method to pre-process and distribute climate values to HRUs outside of a PRMS-only or GSFLOW simulation. An example of a pre-processing method is to specify that GSFLOW compute and then output climate values distributed to each HRU using the climate distribution modules available in GSFLOW. The computation mode of GSFLOW, WRITE_CLIMATE, described below, is used to write Climate by HRU (CBH) files. Because climate data are pre-processed before a simulation, use of `climate_hru` may reduce the run time of a simulation.

Module `climate_hru` reads daily time series of pre-processed climate values from climate-by-HRU (CBH) files. The types of climate values that can be read by the module are (1) daily precipitation, (2) maximum and minimum air temperature, (3) potential evapotranspiration, (4) solar radiation, and (5) active transpiration. To use CBH files, set one or more of the control parameters **temp_module**, **precip_module**, **et_module**, **solrad_module, or transp_module** to `climate_hru` in the Control File for each type of climate values that will be read using CBH files. The filename for the CBH file for each climate type is specified using control parameters **tmax_day**, **tmin_day**, **precip_day**, **potet_day**, **swrad_day, and transp_day**. These filenames are limited to 128 characters. Table 1 below describes the input parameters specified in the Control File for use of the module, table 2 describes input parameters specified in the Parameter File, and table 3 describes the output variables calculated by the `climate_hru` module.

One to five of the climate types (and therefore up to six CBH files) can be read by the `climate_hru` module for each simulation. The remaining climate types can be computed and distributed to each HRU by GSFLOW based on measured values specified in the Data File. For example, if distributed potential evapotranspiration values are not input in a CBH file, they will be computed for

each HRU and time step by the module specified for the value of **potet_module**. Inclusion of measured-data values in the Data File along with specification of values in a CBH file can be helpful for comparison purposes. For example, if a CBH precipitation file is used to input distributed-precipitation values, then measured precipitation values also can be input in the Data File. In any case, a Data File is required for all simulations, even if all climate data are specified in CBH files; at a minimum, the Data File must include columns for the simulation time increments and at least one column of measured values. For example, measured streamflow values could be the only column(s) specified in the Data File.

The input structure for a CBH file is identical to that for the Data File (Markstrom and others, 2008, fig. A1-1). The first line of input consists of a header line of text (up to 256 characters in length). The second line of input consists of the name of the input variable (**hru_ppt**, **tmaxf**, **tminf**, **potet**, **sward,** or **transp_on**), followed by an integer value equal to the number of HRUs. The units for these variables are: **hru_ppt**, in inches or millimeters (as determined by the value of parameter **precip_units**); **tmaxf** and **tminf**, in degrees Fahrenheit or degrees Celsius (as determined by the value of parameter **temp_units**); **potet**, in inches; **swrad**, in Langleys; and **transp_on**, an integer switch using 0 for no transpiration and 1 for transpiration. The third line of input is a delimiter that consists of a single line of at least four pound symbols (####). Comment lines or blank lines can be inserted in the CBH file anywhere between the header line and the delimiter line. (Comment lines begin with two backslashes // in columns 1 and 2.) The remaining lines of input consist of the pre-distributed values for each HRU for each day with each value separated by at least one blank or tab character. The following is an example of a CBH file that specifies precipitation on 6 HRUs for 5 days:

```
Precipitation CBH File
hru_ppt     6
########################################
1996 10  1 0 0 0  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
1996 10  2 0 0 0  0.0145  0.0144  0.0120  0.0118  0.0136  0.0127
1996 10  3 0 0 0  0.0048  0.0048  0.0045  0.0048  0.0047  0.0041
1996 10  4 0 0 0  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
1996 10  5 0 0 0  0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

The data lines for each day can be split into several lines in any CBH file as long as the values are specified in the order from 1 to the number of HRUs. This style of format might be convenient when the HRUs equal the MF cells. The following is an example of a CBH file that specifies precipitation on 12 HRUs for 3 days for a grid consisting of 2 rows and 6 columns:

```
Precipitation CBH File
hru_ppt     12
########################################
1996 10  1 0 0 0
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
1996 10  2 0 0 0
0.0145  0.0144  0.0120  0.0118  0.0136  0.0127
0.0000  0.0000  0.1000  0.0234  0.0000  0.1234
1996 10  3 0 0 0
0.0048  0.0048  0.0045  0.0048  0.0047  0.0041
0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

The pre-processed climate values can be computed and distributed to each HRU using any user-determined method. For example, precipitation can be distributed from a time-series grid, such as from a general circulation model or radar data set, to each HRU with an area-weighted overlay between the precipitation grid map and HRU map. As with standard Data Files, the time period specified in each CBH file can vary, as long as the selected simulation time period, which is specified by control parameters **start_time** and **end_time**, is included within each file.

There is no allowance for missing values when using the `climate_hru` module; thus, the user must ensure that the input values are valid for all HRUs and time steps. The form of precipitation is determined by PRMS in the same manner as all other Precipitation Distribution Modules using parameters **tmax_allrain** and **tmax_allsnow** and the HRU air temperature values. The monthly parameter **adjmix_rain** is used to adjust the amount of rain if a mixed precipitation event is determined based on the calculation of the precipitation form.

Monthly precipitation-adjustment factors are applied by HRU as multiplicative factors (parameters **rain_cbh_adj** and **snow_cbh_adj**) or by subbasin (parameters **rain_sub_adj** and **snow_sub_adj**). Set parameter **adj_by_hru** to 0 to adjust by subbasin and 1 to adjust by HRU. Temperature adjustment factors are applied by HRU as additive factors (parameters **tmax_cbh_adj** and **tmin_cbh_adj**.

Output variables **solrad_tmax** and **solrad_tmin** are set differently by PRMS depending on the parameter **basin_tsta** and the dimension **ntemp**. If **ntemp** is specified greater than 0, which indicates measured air-temperature values are included in the Data File, these variables are set to the measured temperature value for the station specified by **basin_tsta**. Otherwise, **solrad_tmax** and **solrad_tmin** are set to the basin area-weighted value of variable **swrad**. Variable **orad**, can be input as the last column in a solar radiation CBH file. To indicate that values of **orad** are included, set the control parameter **orad_flag** to 1. The following is an example of a CBH file that specifies solar radiation on 6 HRUs for 2 days and the value of **orad** in the last column:

```
Solar radiation CBH File
swrad     6
orad 1
########################################
1980 10  1 0 0 0  494.1610 475.9522 452.7212 471.4162 452.7312 499.0918 452.2661
1980 10  2 0 0 0  481.4671 463.4256 440.3800 458.9292 440.3901 486.4012 439.9359
```

GSFLOW includes an output option to write CBH Files of computed climate by HRU values for each climate type as a time series for the specified simulation time period. To activate this option, set the control parameter **model_mode** (table 1) to the value WRITE_CLIMATE. If this option is selected, GSFLOW reads measured values from the Data File, computes and distributes the climate values to each HRU, and then writes the results to the CBH file(s). The distributed values for each HRU for each day are written to the CBH file(s) with the FORTRAN format specification E10.2. Each timestep is written as a single line.

Each temperature- and precipitation-distribution module requires measured values to be specified in the Data File (refer to pages 154 and 161 in the GSFLOW documentation report by Markstrom and others, 2008, for descriptions of the input requirements for these modules). Measured solar-radiation values and pan-evaporation values are optional because the associated modules use algorithms to compute the distributed values. The GSFLOW or PRMS simulation for model-mode WRITE_CLIMATE only computes climate distribution to each HRU, all other hydrologic processes are not computed; thus, a WRITE_CLIMATE simulation typically executes in a few seconds. The CBH files are written to the user's current directory with the default files defined in table 1. The solar radiation CBH file includes the output variable **orad**. Caution: for a full simulation, remember to set **model_mode** to GSFLOW, PRMS, or MODFLOW after use of the WRITE_CLIMATE mode.

**Table 1.** Input parameters specified in the Control File for the Climate by HRU Distribution Module: climate_hru.

[HRU: hydrologic response unit; Data type: 1, integer; 4, character string; **precip_units**: 0=inches; 1=millimeters; **temp_units**: 0=degrees Fahrenheit; 1=degrees Celsius]

| Parameter name | Definition | Number of values | Data type | Default value |
|---|---|---|---|---|
| | Parameters related to model execution | | | |
| **model_mode** | Model to run (GSFLOW, PRMS, MODFLOW, or WRITE_CLIMATE) | 1 | 4 | GSFLOW |
| **start_time** | Simulation start date and time specified in order as: year, month, day, hour, minute, second | 6 | 4 | 2000, 10, 1, 0, 0, 0 |
| **end_time** | Simulation end date and time specified in order as: year, month, day, hour, minute, second | 6 | 4 | 2001, 9, 30, 0, 0, 0 |
| | Parameters related to model input | | | |
| **orad_flag** | Flag to indicate if the input variable *orad* is included in **swrad_day** input file (0=no; 1=yes) | 1 | 1 | 0 |
| **potet_day** | File name of daily time series of potential evapotranspiration for each HRU (in units of inches) | 1 | 4 | potet.day |
| **precip_day** | File name of daily time series of precipitation for each HRU (in units defined by **precip_units**) | 1 | 4 | precip.day |
| **swrad_day** | File name of daily time series of solar radiation for each HRU (in units of Langleys) | 1 | 4 | swrad.day |
| **tmax_day** | File name of daily time series of maximum air temperature for each HRU (in units defined by **temp_units**) | 1 | 4 | tmax.day |
| **tmin_day** | File name of daily time series of minimum air temperature for each HRU (in units defined by **temp_units**) | 1 | 4 | tmin.day |
| **transp_day** | File name of daily time series of on-versus-off flags for transpiration for each HRU (allowed values are 0 for no transpiration and 1 for transpiration) | 1 | 4 | transp.day |
| | Parameters related to simulation processes (to use pre-processed input values from a climate-by-HRU file for each data type, set module name to `climate_hru`) | | | |
| **et_module** | Module name for potential-evapotranspiration method (climate_hru , potet_jh, potet_hamon, or potet_pan) | 1 | 4 | potet_jh |
| **precip_module** | Module name for precipitation-distribution method (climate_hru, precip_1sta, precip_dist2, precip_laps, or xyz_dist) | 1 | 4 | precip_1sta |
| **solrad_module** | Module name for solar-radiation-distribution method (climate_hru, ccsolrad, climate_hru, or ddsolrad) | 1 | 4 | ddsolrad |
| **temp_module** | Module name for temperature-distribution method (climate_hru, temp_1sta, temp_dist2, temp_laps, or | 1 | 4 | temp_1sta |

| | | | | |
|---|---|---|---|---|
| | xyz_dist) | | | |
| **transp_module** | Module name for transpiration-simulation method (climate_hru or transp_tindex) | 1 | 4 | transp_tindex |

**Table 2.** Input parameters specified in the Parameter File(s) for the Climate by HRU Distribution Module: climate_hru.

[HRU: hydrologic response unit; **one**: a constant (1); **nhru**: number of HRUs; **nmonths**: a constant for number of months in a year (12); **nsub**: number of subbasins; **ntemp**: number of measured air temperature stations input in the Data File]

| Parameter name | Description | Dimension variable | Units | Type | Range | Default value |
|---|---|---|---|---|---|---|
| **adj_by_hru** | Flag to indicate whether to adjust precipitation and air temperature by HRU or subbasin (0=subbasin; 1=HRU) | **one** | none | integer | 0 or 1 | 1 |
| **adjmix_rain** | Monthly (January to December) factor to adjust rain proportion in a mixed rain/snow event | **nmonths** | decimal fraction | real | 0.0 to 3.0 | 1.0 |
| **basin_tsta** | Index of temperature station used to compute solrad_tmax and solrad_tmin when **ntemp** > 0 | **one** | none | integer | 1 to **ntemp** | 1 |
| **hru_subbasin** | Index of subbasin assigned to each HRU | **nhru** | none | integer | 0 to **nsub** | 0 |
| **precip_units** | Flag to indicate the units of input precipitation values (0=inches; 1=millimeters) | **one** | none | integer | 0 or 1 | 0 |
| **rain_cbh_adj** | Monthly (January to December) adjustment factor to measured precipitation determined to be rain on each HRU to account for differences in elevation and so forth | **nhru** by **nmonths** | decimal fraction | real | 0.2 to 5.0 | 1.0 |
| **rain_sub_adj** | Monthly (January to December) adjustment factor to measured precipitation determined to be rain for each subbasin | **nhru** by **nmonths** | decimal fraction | real | 0.0 to 1.0 | 1.0 |
| **snow_cbh_adj** | Monthly (January to December) adjustment factor to measured precipitation determined to be snow on each HRU to account for differences in elevation and so forth | **nhru** by **nmonths** | decimal fraction | real | 0.2 to 5.0 | 1.0 |
| **snow_sub_adj** | Monthly (January to December) adjustment factor to measured precipitation determined to be snow for each subbasin | **nhru** by **nmonths** | decimal fraction | real | 0.0 to 1.0 | 1.0 |
| **temp_units** | Flag to indicate the units of input air-temperature values (0=Fahrenheit; 1=Celsius) | **one** | none | integer | 0 or 1 | 0 |
| **tmax_cbh_adj** | Adjustment to maximum air temperature for each HRU, | **nhru** | **temp_units** | real | -10.0 to 10.0 | 0.0 |

| Parameter name | Description | Dimension variable | Units | Type | Range | Default value |
|---|---|---|---|---|---|---|
| | estimated based on slope and aspect | | | | | |
| **tmax_allrain** | Monthly (January to December) maximum air temperature at which precipitation is assumed to be rain; if HRU air temperature is greater than or equal to this value, precipitation is rain | **nmonths** | **temp_units** | real | 0.0 to 90.0 | 40.0 |
| **tmax_allsnow** | Monthly (January to December) maximum air temperature at which precipitation is assumed to be snow; if HRU air temperature is less than or equal to this value, precipitation is snow | **one** | **temp_units** | real | -10.0 to 40.0 | 32.0 |
| **tmin_cbh_adj** | Adjustment to minimum air temperature for each HRU, estimated based on slope and aspect | **nhru** | **temp_units** | real | -10.0 to 10.0 | 0.0 |

**Table 3.** Output Variables from the Climate by HRU Distribution Module: climate_hru.

[HRU: hydrologic response unit; **one**: a constant (1); **nhru**: number of HRUs; **precip_units**: 0=inches; 1=millimeters; **temp_units**: 0=degrees Fahrenheit; 1=degrees Celsius; ET: evapotranspiration]

| Variable name | Description | Dimension | Units | Type |
|---|---|---|---|---|
| *basin_horad* | Potential shortwave radiation for the basin centroid | **one** | langleys | double |
| *basin_obs_ppt* | Basin area-weighted measured average precipitation | **one** | **precip_units** | real |
| *basin_potet* | Basin area-weighted average of potential ET | **one** | inches | double |
| *basin_potsw* | Basin area-weighted average of potential shortwave radiation | **one** | langleys | double |
| *basin_ppt* | Basin area-weighted average precipitation | **one** | inches | double |
| *basin_rain* | Basin area-weighted average rainfall | **one** | inches | double |
| *basin_temp* | Basin area-weighted average air temperature | **one** | **temp_units** | double |
| *basin_tmax* | Basin area-weighted maximum air temperature | **one** | **temp_units** | double |
| *basin_tmin* | Basin area-weighted minimum air temperature | **one** | **temp_units** | double |
| *basin_transp_on* | Flag indicating whether transpiration is occurring anywhere in the basin (0=no, 1=yes) | **one** | none | integer |
| *basin_snow* | Basin area-weighted average snowfall | **one** | inches | double |
| *hru_ppt* | Precipitation distributed to each HRU | **nhru** | inches | real |
| *hru_rain* | Rain distributed to each HRU | **nhru** | inches | real |
| *hru_snow* | Snow distributed to each HRU | **nhru** | inches | real |
| *is_rain_day* | Flag to indicate if it is raining anywhere in the basin | **one** | none | integer |
| *newsnow* | Flag to indicate if new snow fell on each HRU (0=no; 1=yes) | **nhru** | none | integer |
| *orad* | Measured or computed solar radiation on a horizontal surface | **one** | langleys | real |
| *potet* | Potential ET on each HRU | **nhru** | inches | real |
| *pptmix* | Flag to indicate if precipitation is a mixture of rain and snow for each HRU (0=no; 1=yes) | **nhru** | none | integer |
| *prmx* | Fraction of rain in a mixed precipitation event for each HRU | **nhru** | decimal fraction | real |
| *solrad_tmax* | Basin maximum air temperature for use with solrad radiation calculations | **one** | **temp_units** | real |
| *solrad_tmin* | Basin minimum air temperature for use with solrad radiation calculations | **one** | **temp_units** | real |
| *swrad* | Shortwave radiation distributed to each HRU | **nhru** | langleys | real |
| *tavgc* | Average air temperature distributed to each HRU | **nhru** | degrees Celsius | real |
| *tavgf* | Average air temperature distributed to each HRU | **nhru** | degrees Fahrenheit | real |
| *tmaxc* | Maximum air temperature distributed to each HRU | **nhru** | degrees Celsius | real |
| *tmaxf* | Maximum air temperature distributed to each HRU | **nhru** | degrees Fahrenheit | real |
| *tminc* | Minimum air temperature distributed to each HRU | **nhru** | degrees | real |

| Variable name | Description | Dimension | Units | Type |
|---|---|---|---|---|
| *tminf* | Minimum air temperature distributed to each HRU | **nhru** | Celsius degrees Fahrenheit | real |
| *transp_on* | Flag indicating whether transpiration is occurring (0=no, 1=yes) | **nhru** | none | integer |