The Precipitation-Runoff Modeling System, Software Release Notes Through version 6.0.0, January 22, 2025

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ABSTRACT

The need to assess the effects of variability in climate, biota, geology, and human activities on water availability and flow can be assessed with computer models that simulate the hydrologic cycle at a watershed scale. The Precipitation-Runoff Modeling System (PRMS) is a deterministic, distributed-parameter, physical process-based modeling system developed to evaluate the response of various combinations of climate, water use, and land use on streamflow and general watershed hydrology. The primary objectives of PRMS are: (1) simulate hydrologic processes including evaporation, transpiration, snow accumulation and melt, runoff, infiltration, and interflow as determined by the energy and water budgets of the plant canopy, soil zone, and snowpack on the basis of distributed climate information (maximum and minimum air temperature and precipitation, and depending on climate distribution options selected, potential evapotranspiration, solar radiation, humidity, and windspeed); (2) simulate hydrologic water budgets at the watershed scale for temporal scales ranging from days to centuries; (3) integrate PRMS with other models used for natural-resource management or with models from other scientific disciplines; and (4) provide a modular design that allows for selection of alternative hydrologic-process algorithms from the standard PRMS module library. This release documents describe updates to the PRMS software from previous release through version 6.0.0.

INTRODUCTION

This file describes changes to the Precipitation-Runoff Modeling System (PRMS) with each official release. Modules, file names, and user input are identified by using Courier New font. Input parameters and dimensions are identified by using **bold** font. State and flux variables are identified by using *italic* font. Please also see file **PRMS_tables_6.0.0.pdf** included in the 'doc' directory that provides updates to PRMS-IV tables included in Markstrom and others, 2008 and a new table describing variables related to climate-by-HRU (CBH) files. See the Documentation and Additional Resource section for the full list of PRMS documentation reports and selected application reports.

This release fixes bugs for the computation of:

- some frozen ground dynamics;
- surface runoff, impervious and surface depression storage, and water balance for the rare condition of antecedent snowpack that evaporates on a day, with rainfall and without snowfall and snow;
- possible surface runoff issue for swale HRUs;
- some storage states altered by dynamic parameter values;
- lake_outflow computed with water transfers from lake HRUs;
- snowpack water equivalent values less than the double precision value 0.000000000001 (1.0D-12) are considered to be 0.0 so as to reduce the possibility of floating-point under-

flow and over-flow error conditions in computations associated with the snowpack water equivalent; and

- `precip_map` module was not called.

These fixes, other minor updates, and new functionality are described below in the Version 6.0.0 – January 22, 2025 section starting on page 23.

SYSTEM REQUIREMENTS

PRMS is written in the Fortran 95 and C programming languages. The code has been used on personal computers and super computers running various versions of the Microsoft Windows and Linux operating systems. A typical small model, e.g., around 200 Hydrologic Response Units (HRUs) can be executed on almost all computers. Large models, e.g., greater than 100,000 HRUs may need at least 8 GB of RAM to run effectively. Windows and Linux executables provided in this release are built to run on 64-bit computers. The graphical-user interface (GUI) tool is provided, though no longer supported. Please refer to the Object User Interface (OUI) report (Markstrom and Koczot, 2008) that provides information related to the GUI. Java is required for the GUI, Amazon Corretto is a free Java software than can be downloaded from: https://aws.amazon.com/corretto/.

DOCUMENTATION AND ADDITIONAL RESOURCES

PDF Files identified in bold letters are provided in the "doc" subdirectory. Web page: Precipitation Runoff Modeling System (PRMS) | U.S. Geological Survey (usgs.gov). See Recordings (usgs.gov) for recordings of training course lectures.

Primary Documentation

Markstrom, S.L., Regan, R.S., Hay, L.E., Viger, R.J., Webb, R.M.T., Payn, R.A., and LaFontaine, J.H., 2015, PRMS-IV, the precipitation-runoff modeling system, version 4: U.S. Geological Survey Techniques and Methods, book 6, chap. B7, 158 p., https://dx.doi.org/10.3133/tm6B7. File tm6b7_PRMS-IV.pdf. File **tm6-b7_prms4.pdf**. Note some tables in this report are out of date. See file **PRMS_tables_6.0.0.pdf** included in the '`doc`' directory for the most recent version of these tables.

Additional Documentation

Hay, L.E., LaFontaine, J.H., Van Beusekom, A.E., Norton, P.A., Farmer, W.H., Regan, R.S., Markstrom, S.L., and Dickinson, J.E., 2023, Parameter estimation at the conterminous United States scale and streamflow routing enhancements for the National Hydrologic Model infrastructure application of the Precipitation-Runoff Modeling System (NHM-PRMS): U.S. Geological Survey Techniques and Methods 6–B10, 50 p., https://doi.org/10.3133/tm6B10. File **tm6-10_parameter_estimation.pdf**.

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PRMS PROCESSES, MODULES AND UTILITY ROUTINES

Table 1 describes available process, initialization, and output modules, and utility routines. Modules are written in the FORTRAN programming language. Data-structure and system utility routines are written in the C programming language. Additional modules and routines can be easily added that are written in FORTRAN, C, and other languages that can be linked to FORTRAN. Modules are listed in computation order.

Table 1. PRMS Modules and Utility Routines

[Procedures: SETDIM (define dimension); DECL (define parameters and variables); INIT (set parameters values and initial variable values). Changes for PRMS-6.0.0 are highlighted in blue text]

Module Name	Description	Procedures	Values in Initial Condition File
call_modules	Defines computation sequence, sets dimensions and most control parameters.	all	yes
basin	Defines shared domain wide and HRU parameters and variables, checks validity of parameter values.	DECL and INIT	
cascade	Computes routing order of cascading lateral flows from and to HRUs and to stream segments.	DECL, INIT, CLEAN	
climateflow	Defines and initializes climate and flow parameters used by multiple modules.	DECL, INIT, and CLEAN	yes
soltab	Calculates clear-sky solar radiation and daylight length for each day of the year.	DECL and INIT	
prms_time	Sets daily time variables and saves antecedent states.	DECL, INIT, and RUN	
obs	Sets values read from Data File(s).	SETDIMENS, DECL, INIT, and RUN	
water_use_read	Sets water-use diversions and gains from input files.	DECL, INIT, and RUN	
dynamic_param_read	Sets dynamic parameter values.	DECL, INIT, and RUN	
dynamic_soil_param_read	Sets dynamic parameters for land surface and soil parameters.	DECL, INIT, and RUN	
climate_hru	Sets climate values from pre-processed climate-by-hru (CBH) Files.	DECL, INIT, and RUN	

temp_1sta	Distributes maximum and minimum temperatures to each HRU by using temperature data measured at one station and an estimated monthly lapse rate.	DECL, INIT, RUN, and CLEAN	yes
temp_laps	Distributes maximum and minimum temperatures to each HRU by computing a daily lapse rate with temperature data measured at two stations.	DECL, INIT, RUN, and CLEAN	yes
temp_sta	Distributes maximum and minimum temperatures to each HRU by using a station data, adjusted for distance, measured at each station.	DECL, INIT, RUN, and CLEAN	yes
xyz_dist	Determines the form of precipitation and distributes precipitation and temperatures to each HRU by using a multiple linear regression of measured data from a group of measurement or simulated stations.	SETDIMENS, DECL, INIT, and RUN	
temp_dist2	Distributes maximum and minimum temperatures to each HRU by using a basin-wide lapse rate applied to the temperature data, adjusted for distance, measured at each station.	DECL, INIT, RUN, and CLEAN	yes
ide_dist	Determines the form of precipitation and distributes precipitation and temperatures to each HRU based on measurements at stations with closest elevation or shortest distance to the respective HRU.	DECL, INIT, and RUN	
temp_map	Distributes maximum and minimum temperatures to each HRU as area-weighted averages based on time-series input files with adjustment factors to account for differences in altitude, spatial variation, and topography.	DECL, INIT, and RUN	

precip_1sta	Determines the form of precipitation and distributes it from one or more stations to each HRU by using monthly correction factors to account for differences in altitude, spatial variation, topography, and measurement gage efficiency.	DECL, INIT, and RUN	
precip_laps	Determines the form of precipitation and distributes it to each HRU by using monthly lapse rates.	DECL, INIT, and RUN	
precip_dist2	Determines the form of precipitation and distributes it to each HRU by using an inverse distance weighting scheme.	DECL, INIT, and RUN	
precip_map	Determines the form of precipitation to each HRU as area-weighted averages based on a time-series input file with adjustment factor to account for gage efficiency.	DECL, INIT, and RUN	
frost_date	Preprocess module to determine the latest killing frost date in the spring and the earliest date in the Fall for each HRU for the simulation time period when **model_mode** specified as FROST.	DECL, INIT, RUN, and CLEAN	
ddsolrad	Distributes solar radiation to each HRU and estimates missing solar radiation data using a maximum temperature per degree-day relation.	DECL, INIT, and RUN	
ccsolrad	Distributes solar radiation to each HRU and estimates missing solar radiation data using a relation between solar radiation and cloud cover.	DECL, INIT, and RUN	
transp_tindex	Determines whether the current time step is in a period of active transpiration by the temperature index method.	DECL, INIT, RUN, and CLEAN	yes
transp_frost	Determines whether the current time step is in a period of active transpiration by the killing frost method.	DECL, INIT, and RUN	

potet_jh	Computes the potential evapotranspiration by using the Jensen-Haise formulation.	DECL, INIT, and RUN	
potet_hamon	Computes the potential evapotranspiration by using the Hamon formulation.	DECL, INIT, and RUN	
potet_pan	Computes potential evapotranspiration by using pan-evaporation data.	DECL, INIT, RUN, and CLEAN	yes
potet_pt	Computes the potential evapotranspiration by using the Priestley-Taylor formulation.	DECL, INIT, and RUN	
potet_pm_sta	Computes the potential evapotranspiration for each HRU by using pan-evaporation data.	DECL, INIT, and RUN	
potet_pm	Computes the potential evapotranspiration by using the Penman-Monteith formulation.	DECL, INIT, and RUN	
potet_hs	Computes the potential evapotranspiration by using the Hargreaves-Samani formulation.	DECL, INIT, and RUN	
write_climate_hru	Preprocess module to write distributed air minimum and maximum temperature, precipitation, potential solar radiation and potential evapotranspiration by HRU to files for use by climate_hru module for the simulation time period when **model_mode** specified as WRITE_CLIMATE.	DECL, INIT, RUN, and CLEAN	
intcp	Computes volume of intercepted precipitation, evaporation from intercepted precipitation, and throughfall that reaches the soil or snowpack.	DECL, INIT, RUN, and CLEAN	yes
snowcomp	Initiates development of a snowpack and simulates snow accumulation and depletion processes by using an energy-budget approach.	DECL, INIT, RUN, and CLEAN	yes

glacr	Computes glacier dynamics using three linear reservoirs (snow, firn, and ice).	all	yes
srunoff_smidx	Computes surface runoff and infiltration for each HRU by using a nonlinear variable-source-area method allowing for cascading flow.	DECL, INIT, RUN, and CLEAN	yes
srunoff_carea	Computes surface runoff and infiltration for each HRU by using a linear variable-source-area method allowing for cascading flow.	DECL, INIT, RUN, and CLEAN	yes
soilzone	Computes inflows to and outflows from the soil zone of each HRU and includes inflows from infiltration, groundwater, and upslope HRUs, and outflows to gravity drainage, interflow, and surface runoff to down-slope HRUs.	DECL, INIT, RUN, and CLEAN	yes
gwflow	Sums inflow to and outflow from PRMS groundwater reservoirs; outflow can be routed to downslope groundwater reservoirs and stream segments;	DECL, INIT, RUN, and CLEAN	yes
routing	Defines and computes common streamflow routing values for strmflow_in_out, muskingum, muskingum_mann, and muskingum_lake.	DECL, INIT, RUN, and CLEAN	yes
strmflow	Computes daily streamflow as the sum of surface runoff, shallow-subsurface flow, detention reservoir flow, and groundwater flow.	DECL and RUN	
muskingum	Routes water between stream segments using Muskingum routing method.	DECL, INIT, RUN, and CLEAN	yes
muskingum_mann	Routes water between stream segments using Muskingum routing method based on Manning's channel roughness coefficient.	DECL, INIT, RUN, and CLEAN	yes
strmflow_in_out	Routes water between segments in the system by setting the outflow to the inflow.	DECL and RUN	

muskingum_lake	Routes flow between stream segments and on-channel lakes using Muskingum routing for stream segments with six options for lake outflow and storage.	all	yes
segment_to_hru	Routes stream segment output to specified HRU(s) capillary reservoir, useful for terminal streams.	DECL, INIT, and RUN	
strmflow_character	Computes stream segment characteristics (width, depth, area, velocity, and residence time) with the stream_temp is active.	DECL, INIT, and RUN	
stream_temp	Computes stream temperature based on SNTEMP method.	DECL, INIT, RUN, CLEAN	yes
basin_sum	Computes daily, monthly, yearly, and total flow summaries of volumes and flows for all HRUs.	DECL, INIT, RUN, and CLEAN	yes
water_balance	Computes water balance components when **print_debug** specified as 1.	DECL, INIT, RUN, and CLEAN	
map_results	Writes HRU summaries to a user specified target map at weekly, monthly, yearly, and total time steps.	DECL, INIT, RUN, and CLEAN	
subbasin	Computes streamflow at internal basin nodes and HRU variables by subbasin.	DECL, INIT, and RUN	
nhru_summary	Writes specified **nhru**, **nssr**, and/or **ngw** variables to time-series files.	DECL, INIT, RUN, and CLEAN	
nsub_summary	Writes specified **nhru**, **nssr**, and/or **ngw** variables summarized to subbasin to time-series files.	DECL, INIT, RUN, and CLEAN	
basin_summary	Writes specified basin variables to a time-series file.	DECL, INIT, RUN, and CLEAN	
nsegment_summary	Writes specified nsegment variables to time-series files.	DECL, INIT, RUN, and CLEAN	
prms_summary	Writes a set of basin variables to a time-series file.	DECL, INIT, RUN, and CLEAN	

`convert_params`	Preprocess and convert parameters changed between PRMS IV and PRMS5 when model_mode is specified as CONVERT		

FREQUENTLY ASKED QUESTIONS

CONTROLLING SCREEN OUTPUT

There can be a large amount of information printed to the screen, including general information, warning messages, and error messages during initialization of a simulation. Sometimes the volume of screen output can make it difficult to see error messages. There are three options to reduce screen output. Set control parameter **parameter_check_flag** to 0 in the Control File to minimize warning messages about parameter values falling outside the suggested range. Set control parameter **print_debug** to -2 (minimum output, including not producing the PRMS **model_output_file**) or -1 (less output). However, setting **parameter_check_flag** = 1 and **print_debug** = 0 is good practice during initial model development as all warning and error messages are printed. But, once warnings are deemed acceptable, **parameter_check_flag** should be set to 0 and **print_debug** to -1 or -2 to decrease execution time.

FLEXIBLE SPECIFICATION FOR PARAMETERS

There are several ways to specify parameters. Traditionally, a single value is specified per line in the Parameter File. However, multiple values can be specified per line with a limit of 12,000 characters, including spaces per line. Lines with multiple values cannot end with blank character(s). Use of multiple values per line can be used to specify parameter values as a grid of columns by rows with the upper left value specified for HRU 1 and the lower right value for HRU **nhru**.

Prior to version 4.0.1, parameters had to be specified with the number of values determined by the dimension(s) as defined in table 1.3 of the PRMS documentation. Dimensions are defined in table 1.1. See file **PRMS_tables_6.0.0.pdf** included in the '`doc`' directory for the most recent version of these tables. Now the user has several options to specify the number of parameter values based on the spatial and temporal variability, available data, or for some other purpose.

Parameters can be specified by the dimension(s) defined in table 1.3 (referred to herein as the maximum dimension(s)) or using compatible dimensions with the maximum dimension(s). There are 6 options for specifying a parameter with dimensions **nhru**,**nmonths**: 4 using a single dimension: **one**, **nmonths**, **nsub**, or **nhru**, and 2 using two dimensions: **nsub**,**nmonths**, and **nhru**,**nmonths**. There are 3 options for a parameter with dimension of **nhru**: **one**, **nsub**, and **nhru**. The dimension options for a parameter with a maximum dimension of **nssr** are **one**, **nsub**, and **nssr**. The dimension options for a parameter with a maximum dimension of **ngw** are **one**,

nsub, and **ngw**. PRMS reads the dimension, number of values, and values from the Parameter File. If the parameter is not specified at the maximum dimension(s), the parameter values will be automatically expanded to the maximum dimension by the code.

Using subsets of the maximum dimensions and/or multiple values on lines can significantly reduce the size and number of lines in a Parameter File. The most used option is to specify parameters with the dimension **one** or **nsub** values for parameters that have a constant value for all HRUs or subbasins, respectively.

Additionally, the maximum dimension(s) for some parameters have been increased since version 4.0.1. Increasing the maximum number of values was added to accommodate simulation of large model domains that required increased spatial and/or temporal distribution of parameter values. For example, some parameters having dimension of **nmonths** now have a maximum dimension of **nhru**,**nmonths** and some parameters having dimension of **nhru** now have a maximum dimension of **nhru**,**nmonths**. Note, that using different number of values may change results when dimensions are specified greater than dimension(s) defined for older models while allowing for increased ability to calibrate spatially and temporally.

Using different number of values may change results when dimensions are specified greater than the original dimension(s) of older models while allowing for increased ability to calibrate spatially and temporally.

INITIAL CONDITIONS FILES

The Initial Conditions File is read whenever control parameter **init_vars_from_file** is specified > 0. This file must be created by the same model executable that is used in a restart simulation. Various initial states can be updated for a restart simulation using initial value parameters as specified in the Parameter File depending on the value of **init_vars_from_file**:

0 = do not read Initial Conditions File and use all initial value parameters as read from Parameter File;
1 = read all initial value parameters;
2 = read **dprst_frac_init**, **snowpack_init**, **segment_flow_init**, **elevlake_init**, **gwstor_init**, (**soil_rechr_init**, **soil_moist_init**, **ssstor_init** for model_mode = `PRMS`) or (**soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac** for model_mode = `PRMS5`), and **stream_tave_init**;
3 = read **snowpack_init**;
4 = read **elevlake_init**;
5 = read (**soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac** for model_mode = `PRMS5`;
6 = read **gwstor_init**;
7 = read **dprst_frac_init**;
8 = read **stream_tave_init**.

Options 2 and 3 could be used, for example, to update the snowpack in a restart simulation by specifying values for **snowpack_init** to reflect an observed or model snow water equivalent data set. Option 8 could be used, for example, to update the stream temperature in each segment in a restart simulation by specifying values for **stream_tave_init** to reflect an observed or modeled stream temperature data set.

Things that cannot change for a restart simulation include: a) surface depression storage simulation option; b) cascading flow simulation option; c) dimensions **nhru**, **nssr**, **ngw**, **nsegment**, **nhrucell**, **nlake**; d) the model mode; and e) use of modules temp_1sta, temp_laps, temp_dist2, potet_pan, transp_tindex.

MODEL MODES

The control parameter **model_mode** is used to specify a variety of simulation and output options. If **model_mode** is not specified, the default value is PRMS5. The available values of **model_mode** are:

PRMS5 or prms5 – These modes use the parameters **tmax_allrain_offset**, **soil_rechr_max_frac**, **soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac**, **sro_to_dprst_perv**, and **dprst_frac**.

PRMS, prms, PRMS4, prms4, or DAILY – These modes use the parameters **tmax_allrain**, **soil_rechr_max**, **soil_rechr_init**, **soil_moist_init**, **ssstor_init**, *sro_to_dprst*, and **dprst_area**.

DOCUMENTATION – This mode generates a Parameter File (control file name plus suffix .param), a file of parameter definitions (control file name plus suffix .par_name), and a file of variable definitions (control file name plus suffix .var_name) as if all simulation options are active. The generated Parameter File contains all parameters, at their maximum dimension, that are needed for all modules and simulation options in the functionality list above. No hydrologic processes are simulated. The command line option -print must be specified. When the command line option -print is specified for any **model_mode** other than DOCUMENTATION these files include parameters and variables for the active modules and simulation options as specified by values in the Control File. These _name files provide documentation of parameters and variables that can be used in lieu of the file PRMS_tables_5.2.pdf though in a less readable format. All parameters are expanded to their maximum dimension(s) and written to the .param file. If a parameter is included in the Parameter File(s) the values are written as specified. Parameters that are required by the set of modules that are not included in the Parameter File(s) are written with their default value(s). Parameters specified in the Parameter File(s) that are not required by the set of modules executed are not written to the .param file.

CONVERT – This mode computes and produces the file PRMS_5.params that contains parameters **tmax_allrain_offset**, **soil_rechr_max_frac**, **soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac**, **sro_to_dprst_perv**, and **dprst_frac** used in a PRMS5 simulation on the basis of an existing Parameter File used with a PRMS4 simulation. This file can be added to the Parameter File or input as another Parameter File. Parameters **tmax_allrain**, **soil_rechr_max**, **soil_rechr_init**, **soil_moist_init**, **ssstor_init**, **sro_to_dprst**, and **dprst_area** can be removed from the existing Parameter File.

`CONVERT4` – This mode computes and produces the file `PRMS_4.params` that contains parameters **tmax_allrain**, **soil_rechr_max**, **soil_rechr_init**, **soil_moist_init**, **ssstor_init**, **sro_to_dprst**, and **dprst_area** used in a PRMS4 simulation on the basis of an existing Parameter File used with a PRMS5 simulation. This file can be added to the existing Parameter File or input as another Parameter File. Parameters **tmax_allrain_offset**, **soil_rechr_max_frac**, **soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac**, **sro_to_dprst_perv**, and **dprst_frac** can be removed from the existing Parameter File.

`FROST` – This mode computes and writes the file `frost_date.param` of frost parameters (**spring_frost** and **fall_frost**) using the `frost_date` module that can be used by the `transp_frost` module in subsequent simulations. This file can be added to the existing Parameter File or input as another Parameter File. This mode reads input files (Data, CBH, Dynamic Parameter, and Water-Use) and computes temperature and precipitation processes. All other processes are not computed.

`WRITE_CLIMATE` – This mode computes and writes Climate-by-HRU (CBH) File(s) for all climate processes that have the control parameters **precip_module**, **temp_module**, **et_module**, **swrad_module**, and/or **transp_module** specified equal to **climate_hru**. The filenames for CBH Files are specified by a control parameter: **precip_day** (precipitation in units defined by **precip_units**); **tmax_day** and **tmin_day** (air temperature in units defined by **temp_units**); **potet_day** (potential evapotranspiration in inches/day); **swrad_day** (for solar radiation in Langleys); and **transp_day** (transpiration as values 0 (off) or 1 (on)). The generated CBH File(s) can be used by the **climate_hru** module in subsequent simulations. The simulation reads input files (Data, CBH, Dynamic Parameter, and Water-Use) and computes temperature, precipitation, solar radiation, transpiration, and potential evapotranspiration processes, and writes requested CBH files. All other processes are not computed.

`CLIMATE` – This mode computes climate processes only. The simulation reads input files (Data, CBH File, Dynamic Parameter, and Water-Use) and computes temperature and precipitation. All other processes are not computed.

`POTET` – This mode computes processes through potential evapotranspiration. The simulation reads input files (Data, CBH, Dynamic Parameter, and Water-Use) and computes temperature, precipitation, solar radiation, transpiration, and potential evapotranspiration processes. All other processes are not computed.

`TRANSPIRE` – This mode computes processes through transpiration (active growing season). The simulation will only read input files (Data, CBH, Dynamic Parameter, and Water-Use) and compute temperature, precipitation, solar radiation, and transpiration. All other processes are not computed.

ERROR CODES

When a simulation normally ends the return code is 0. If an error is encountered one of the following return codes is issued. When an error occurs an error message is issued, and the simulation stops.

Open of output file error	-3
Open of input file error	-2
Write to output file error	-1
Control File read error	1
Dimension error	3
Parameter error	4
Data File error	5
Simulation time error	6
Temperature error	7
Streamflow routing error	8
Basin parameter error	9
Climate-by-HRU read error	10
Cascade error	11
Initial Conditions error	12
Dynamic parameter error	13
Water use error	14
Read or declare error	15
Module error	16
Muskingum lake error	17
Interflow error	18

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Version 6.0.0 – January 22, 2025

This release fixes bugs in the computation of: (a) frozen ground dynamics in `srunoff_smidx`, `srunoff_carea`, and `soilzone`; (b) surface runoff, impervious and surface depression storage, and water balance for the rare condition of antecedent snowpack that evaporates on a day, with rainfall and without snowfall and snow melt in `srunoff_smidx`, `srunoff_carea`, and `water_balance`; (c) surface runoff in swale HRUs in `srunoff_smidx` and `srunoff_carea`; (d) some storage states altered by dynamic parameter values; these fixes were made in code related to soil, impervious, and surface depression storage that was moved from file `dynamic_param_read.f90` to new file `dynamic_soil_param_read.f90`; (e) fluxes related to impervious and surface-depression storage parameters are initialized for all HRUs as these parameters could change an

HRU to have or not have impervious fractions; and (f) lake outflow for lake water-use transfers in muskingum_lake. Additionally, precip_map was only called for **model_mode** = DOCUMENTATION, now it is available for all values of **model_mode**. Old Initial Condition Files file must be created by this release to be used in a restart simulation.

Mixed precision computations and comparisons that were not explicit were made explicit by increased use of intrinsic functions and double precision constants. These changes may lessen the effects of floating-point, round-off error in computing surface depression storage, cascading flow computations, and snow dynamics. This change may result in slightly different simulation results between compilers and in other rare cases.

This version adds new functionality: (a) stream temperature replacement for identified segment(s) using values specified in the Data File; (b) option to turn off simulation of snow and glacier dynamics; (c) option to limit values input in CBH Files to a specified subset of HRUs, such as only active HRUs; (d) option to route streamflow from segments to the capillary reservoir of an associated HRU that may be important for recharge and actual evapotranspiration in HRUs with terminal streams, especially during high precipitation events; (e) option to output nhru_summary output files in a binary format; and (f) option to address bias towards minimum air temperature when computing the fraction of rain for mixed events and temperature of rain added to snowpack using new control parameter **bias_adjust_flag**.

Changes to parameter descriptions, default value, and suggested minimum and maximum values are identified in file **PRMS_tables_6.0.0.pdf** with blue text. Modified parameters are: **lat_temp_adj**, **pt_alpha**, **rain_adj**, **snow_adj**, **rain_mon**, **snow_mon**, **psta_mon**, **adjust_snow**, **adjust_rain**, **hs_krs**, **adjmix_rain**, **radj_sppt**, **radj_wppt**, **poi_type**, **pt_alpha**, **soil_rechr_max**, **soil_moist_max**, **cascade_tol**, **tmax_cbh_adj**, **tmin_cbh_adj**, **rain_cbh_adj**, **snow_cbh_adj**, and **potet_cbh_adj**.

Changes are described below that are more than format, spelling changes in comments and information messages, adding routine declarations, removal of unused variables, and adding additional information to warning and error messages that were made to increase a consistent coding style across the files. Note the acronym DPRST refers to surface-depression storage.

CODE CHANGES THAT DO NOT AFFECT SIMULATION RESULTS AND MAY AFFECT OUTPUT

- Version dates of modules were updated to the day the module was last modified.
- Code, parameters, and variables specific to GSFLOW are removed from files call_modules.f90, climateflow.f90, basin.f90, soilzone.f90, subbasin.f90, and setup_cont.c.
- Use colon ":" to specify the first dimension of two-dimensional arrays passed as arguments to routines instead of the number 1. This is more portable coding between FORTRAN compilers. Files affected are soltab.f90, nsegment_summary.f90, nsub_summary.f90, map_results.f90, xyz_dist.f90, glacr_melt.f90,

`dynamic_param_read.f90`, `dynamic_soil_param_read.f90`, and `snowcomp.f90`.

- Save antecedent values of variables *soil_moist*, *ssres_stor*, *basin_ssstor*, *basin_soil_moist*, *pkwater_equiv*, *dprst_stor_hru*, and *hru_impervstor* in variables *It0_soil_moist*, *It0_ssres_stor*, *It0_basin_ssstor*, *It0_basin_soil_moist*, *It0_pkwater_equiv*, *It0_dprst_stor_hru*, and *It0_hru_impervstor*, respectively. These "It0_" variables make up the new Fortran module PRMS_IT0_VARS and are set at the beginning of each time step in `prms_time`. This reduces circular dependencies related to dynamic parameters by saving these values at the beginning of each time step instead of in associated modules. *It0_pkwater_equiv* can be written to summary output files.
- Moved variables *soil_zone_max*, *pref_flow_stor*, and *soil_lower_stor_max* to Fortran module PRMS_FLOWVARS defined in file `climateflow.f90` from their associated modules. This change affects files `soilzone.f90`, `subbasin.f90`, `dynamic_soil_param_read.f90`, and `water_balance.f90`. This was done reduce circular dependencies between modules resultant from use of some dynamic parameters and simplifies computation of optional water balances.
- Removed unnecessary initialization of variables in files `ccsolrad`, `obs`, `prms_summary`, `muskingum`, `subbasin`, `intcp`, `transp_frost`, `routing`, `climate_hru`, `gwflow`, `climateflow`, `water_balance`, `srunoff_smidx`, `srunoff_carea`, `soilzone`, and `snowcomp`. This change shortens initialization time requirements.
- Add error checks for control parameter **start_time** is before **end_time** and for **nhru**, **nssr**, **ngw** not being the same value.
- Add print of Github Hash tag to screen and model output file when **print_debug** is specified > -1.
- Address compile time security warnings, unused interfaces and control parameters, and inconsistent string sizes in files `batch_run_functions.c`, `declparam.c`, `declvar.c`, `defs.h`, `setup_cont.c`, `protos.h`, `read_control.c`, and `read_params.c`.
- For special model modes `CLIMATE`, `TRANSPIRE`, `WRITE_CLIMATE`, `POTET`, `FROST`, always return, i.e., don't call process modules later in computation sequence. Modes `CLIMATE`, `TRANSPIRE`, and `POTET` produce `statvar`, `animation`, `runtime plots`, `nhru_summary`, `nsub_summary`, `basin_summary`, and `nsegment_summary` files if any of these options are active. Verify that variables specified in the Control File for these output options are valid for the limited number of processes computed.
- Increase code efficiency by changing floating point comparisons using <= or >= to "not >" and "not <", respectively. This change was made in a few comparisons in `snowcomp`,

srunoff_smidx, srunoff_carea, climateflow, and water_balance and has not resulted in any noticeable change in results.

- Increase use of array assignments to initialize variables instead of within DO loops in files routing, snowcomp, srunoff_smidx, srunoff_carea, and soilzone. This ensures flow variables related to dynamic parameters are initialized for all HRUs.
- Increase code efficiency by checking **segment_type** for values > 0. This is done once instead of checking **segment_type** values each timestep in files routing, muskingum, strmflow_in_out, and muskingum_lake.
- Added print of HRU identification number if issue is detected in determination of precipitation form.
- Set *humidity_hru* inside main DO loop instead of array assignment in files potet_pm and potet_pt.
- Removed code associated with reading binary formatted CBH Files when control parameter **cbh_binary_flag** was specified equal to 1 as this option did not work correctly. Added routine find_cbh_header_end to climate_hru from code in routine find_header_end in utils_prms that is called for CBH Files. Code and arguments are removed from routine find_header_end used in dynamic_param_read, dynamic_soil_param_read, nhru_summary, precip_map, temp_map, and water_use_read. Additionally routine find_current_time was modified to remove **cbh_binary_flag**.

glacr_melt

- Use **hru_slope** from soltab.
- Use *obliquity* and *solar_declination* as computed in soltab instead of recomputing in routine recompute_soltab.

defs.h

- Maximum characters that can be read per line from the Data File is changed from 12000 to 60000 to accommodate the large number of streamflow values specified in the National Hydrologic Model (NHM) Data File.

stream_temp

- Add error check for **seg_humidity_sta** > **nhumid**.

muskingum_lake

- Error check added for **obsout_lake** values > **nobs**.

temp_1sta_laps

- Module name was printed incorrectly when **temp_module** is specified equal to temp_sta.

basin_sum

- Glacier variables *basin_glacrb_melt*, *basin_glacrevap*, and *basin_gl_to_melt* and lake variable *basin_2ndstflow* added to computation of the basin water balance.
- Add error check for **outlet_sta** value greater than **nobs**.
- Initial value of *basin_storage* now includes *basin_segment_storage* and *basin_storage* is printed as F10.3 instead for F9.3 to accommodate large model domains.

`water_balance`

- Subtract *basin_soil_to_gw* when computing the basin capillary zone water balance as this soil infiltration water bypasses the capillary reservoir.
- Computation of *basin_dprst_wb* is now initialized for each timestep.
- Subtract *basin_dunnian* from computation of the surface runoff water balance as it is computed in `soilzone.f90` instead of `srunoff.f90` and included in *sroff*.
- Added additional variables and organized debug output for water balance issues.
- fix double counting *net_rain* when antecedent snowpack, that evaporates due to rain without any snow or snow melt in calculation of the HRU surface runoff water balance and overall water balance.

`write_climate_hru`

- Variables *tmax*, *tmin*, and *hru_ppt* are written based on **temp_units** and **precip_units** instead of always Fahrenheit and inches.

`climate_hru`

- Use constant MM instead of CELSIUS to check **precip_units**.
- Added additional error checks for values in CBH Files.
- For each data type input in a CBH File, print `climate_hru` as the module name. Previously, `climate_hru` was printed once no matter how many CBH Files were input.
- Added routine for reading CBH values to replace duplicate code.

`nhru_summary`

- Values for the last day of each month were not included when computing mean monthly values (control parameter **nhruOut_freq** specified equal to 4).
- If **nhruOutNcol** is specified other than a multiple of nhru the number of values on the last output row is calculated.
- When writing gridded output and the number of columns requested is not an even multiple of nhru an additional row is added with the number of values equal to the remainder of **nhru**/**nhruOutNcol**.

`soilzone`

- Set initial value of *ssres_stor* equal to *slow_stor* + *pref_flow_stor* to be consistent. pref_flow_stor is 0.0 in a non-restart simulation, so no change to results.

- Determine if preferential flow reservoir is active on any HRU by getting the maximum value of **pref_flow_den**. If preferential flow reservoirs are not present a flag is set so that allocation of some arrays and computations related to preferential flow reservoirs are skipped to speed up execution time and reduce memory requirements.
- Variable *hru_sz_cascadeflow* was not reset to 0 if cascading flow in previous timestep and inter flow + Dunnian flow > 0.000001. This change affects the values of *hru_sz_cascadeflow* and *basin_dncascadeflow* that are only used to compute optional water balance.
- Warning message for *lake_evap* > potet due to **lake_evap_adj** values > 0.0 are only printed when **print_debug** > -1.

`climateflow`

- Set **hru_pansta** whenever **nevap** > 0, not just when **et_module** = `potet_pan` as it is also used in `intcp`.
- Compute initial value of *basin_soil_moist* and *basin_ssstor* to set *lt0_basin_soil_moist* and *lt0_basin_ssstor*, respectively, to correctly compute the optional water balance on the first timestep.
- Require **humidity_percent** only when `potet_pm` or `potet_pt` are active and **humidity_cbh_flag** = 0 instead of whenever **humidity_cbh_flag** = 0.
- Print of values for error messages changed from F10.5 to F15.9.

`precip_dist2`

- Check for **max_psta** > **nrain** if true set **max_psta** = **nrain**
- Check **psta_mon** specified < 0.000001, if true the simulation stops if **parameter_check_flag** > 0; if **parameter_check_flag** = 0 a warning message is printed and **psta_mon** is set to 0.000001.
- Use constant MM instead of CELSIUS to check **precip_units**.

`basin`

- Change error check for *hru_frac_perv* < 0.00099 to < 0.00001.
- Add error checks for **hru_percent_imperv** and **dprst_frac** > 0.99999.

`srunoff_smidx` and `srunoff_carea`

- Check for glacier HRUs fraction = 0.0, if true treat HRU as land HRU for infiltration and surface runoff purposes to increase code efficiency.

BUG FIXES AND CHANGES THAT MAY AFFECT SIMULATION RESULTS

Most of these changes are related to swales, frozen ground when **frozen_flag** = 1, glacier HRUs when **glacier_flag** = 1, and/or dynamic parameters are specified. Most changes described below may result in none or very slight change in results depending on model configuration.

To reduce inconsistencies and lessen round-off error for very small snowpacks the global variable ZERO_SNOWPACK, set to 1.0D-12, is added to `prms_constants.f90` and used in `snowcomp`, `intcp`, `water_balance` to check the value of *pkwater_equiv*. Previously, checks used 0.0D0 or epsilon(0.0D0), which is approximately 2.220446049250313E-016. If the *pkwater_equiv* becomes < ZERO_SNOWPACK in `snowcomp` snowpack variables are set to zero. Use of ZERO_SNOWPACK may change results slightly.

Reduce mixed precision calculations and comparisons and make explicit using intrinsic functions in files `strmflow_in_out`, `routing`, `snowcomp`, `gwflow`, `glacr_melt`, `stream_temp`, `basin_sum`. It is possible this could cause slight changes to results between different compilers.

Add *hru_frac_imperv* and *hru_frac_dprst* as dynamic parameters may change values of **hru_percent_imperv** and **dprst_frac**, respectively. This change affects `basin`, `srunoff_smidx`, `srunoff_carea`, `dynamic_soil_param_read`, and `water_balance`.

Add *Imperv_flag* to indicate if there is any impervious area in the model domain. Dynamic parameters may change from/to inclusion or removal of impervious fractions in the model domain. This change affects `basin`, `call_modules`, `srunoff_smidx`, `srunoff_carea`, `dynamic_param_read`, and `dynamic_soil_param_read`.

Allow swale HRUs to be frozen instead of error. This affects `basin` and `soilzone`.

Initialize many variables using array assignment outside instead of within the main DO loop in `snowcomp`, `srunoff_smidx`, `srunoff_carea`, `soilzone`, and `snowcomp`. This change may affect results when dynamic DPRST parameters are specified.

The value of *intcp_changeover* is added to *net_rain* as throughfall in `intcp` to simplify computation of infiltration, DPRST, snow dynamics, and water balance. Previously *intcp_changeover* was not included in computation of snow dynamics in `snowcomp`. Note, *intcp_changeover* is rarely > 0.0 and if so, is most often very small. Adding *intcp_changeover* > 0.0 to *net_rain* when *intcp_changeover* > 0.0 means *net_rain* + *net_snow* is > than *net_ppt*. Conditions where *intcp_changeover* is > 0.0 are:

- For a day where transpiration is active, and the previous day was inactive and **covden_sum** = 0 all storage falls as throughfall.
- For a day when transpiration is inactive and was active on the previous day, such as change from summer to winter season and **covden_sum** - **covden_win** > 0.0. Throughfall is storage based on the ratio of **covden_sum** to **covden_win** while maintaining the depth of storage in the canopy.
- If **cov_type** is changed to bare ground (**cov_type**=0) from another cover type through dynamic parameter input, canopy storage falls as throughfall.

`muskingum_lake`

- For water use withdrawals from lake HRUs, *lake_transfer* was subtracted instead of added to *lake_outflow*.

`gwflow`

- Set *gwres_stor* = 0.0D0 if computed < 0.0D0 that may happen with the water use option.

`srunoff_smidx`, `srunoff_carea`, and `water_balance`

- Variable *net_rain* was added twice for the very rare condition when there was an antecedent snowpack that evaporated and *net_rain* is greater than 0.0, *net_snow* equals 0.0, and *snowmelt* equals 0.0. The double counting of *net_rain* affected impervious, DPRST, and soil infiltration computations. Note, new water for surface runoff and water balance computations can be snowmelt, throughfall, changeover throughfall from season changes or dynamic parameters, irrigation application, cascading Hortonian runoff, and glacier melt.

`snowcomp`

- The value of *intcp_changeover* was not added to the snowpack, it is now included in *net_rain*.
- When a snowpack melts or evaporates, snow states are set to 0.0 using new routine `snow_states_to_zero` so that snow states are initialized consistently. This may change values for some snowpack variables as initializing snowpack states was inconsistent when a snowpack disappears on a time step through melt and/or evaporation.
- Add value of *pk_ice* to *freeh2o* if *pk_ice* < 0.0, if *freeh2o* < 0.0 set to 0.0. This change affects some states of the snowpack but not the water budget.

`srunoff_smidx` and `srunoff_carea`

- New water available for surface runoff and infiltration is adjusted for partially glaciated HRUs based on 1.0 - **glacier_frac** when **glacier_flag** > 0. Recommended that glacier HRUs not include impervious area, irrigation application, or cascade flow.
- Additional checks added so that surface runoff is not computed for swale HRUs (**hru_type**=3).
- Irrigation application water is now applied to DPRST in addition to the pervious and impervious fractions.
- Changed floating point comparisons using < 0.000001 to “not > 0.0” for some DPRST computations.
- Fixes related to computation of frozen ground dynamics for HRUs determined to be frozen by the continuous frozen ground index (CFGI) method when **frozen_flag** = 1:
  a) DPRST is assumed to be frozen, new water, including surface runoff from the pervious and impervious fractions and precipitation is added to storage.
  b) DPRST seepage and evaporation are computed.

c) New water to impervious areas is added to *sroff*; except for swale HRUs where this water is added to impervious storage.
d) Evaporation is computed for impervious fraction.
e) Irrigation application (*net_apply*) is added to sroff; for swale HRUs *net_apply* is added to *infil*.
f) New water to pervious fraction is added to sroff and *infil* is set to 0.0.
g) New water to swale HRUs is added to *infil* instead of *sroff*.

- If impervious storage, DPRST storage and surface, or cascading surface runoff are computed to values less than 0.0 for any HRU those values are set to 0.0. This is a rare condition that can occur due to round-off error.
- If contributing area is computed less than 0.0 surface runoff is set to 0.0. This is a rare condition that can occur due to round-off error or inconsistent parameter values.
- Initialize impervious fluxes for all HRUs in case **hru_percent_imperv** values for HRUs are changed from having to not having impervious fraction as for this condition fluxes retained values from previous time step for the remainder of the simulation unless changed to having impervious.
- Initialize DPRST fluxes for all HRUs in case **dprst_frac** values for HRUs are changed from having to not having DPRST fraction as for this condition fluxes retained values from previous time step for the remainder of the simulation unless changed back to having DPRST.
- Cascading runoff is computed when sroff > 0.000001 instead of > 0.0 when **cascade_flag** > 0.

`soilzone`

- Fixes were made related to computation of frozen ground dynamics:
  a) Soil infiltration and cascading flow that was to be added to capillary reservoir storage is added to *sroff*, *hortonian_flow*, *basin_hortonian*, and *basin_sroff*.
  b) Water computed to be added to preferential reservoir storage from gravity reservoir storage is left in preferential-flow reservoir storage, thus preferential flow storage (*pref_flow_stor*) can exceed the maximum water holding capacity until the frozen ground condition ends when this excess water is released as Dunnian surface runoff.
  c) Allow swales to be frozen, new water is added to capillary storage (*soil_moist* and *soil_rechr*) and to preferential flow reservoir storage.
- If unsatisfied potential evapotranspiration is computed less than 0.0, print warning and set the value to 0.0. This is a rare condition that can occur due to round-off error.
- If *hru_actet* is computed > *potet* set the value to *potet*. This is a rare condition that can occur due to round-off error.
- If unsatisfied PET is computed less than 0.0, set *hru_actet* to *potet*. This is a rare condition that can occur due to round-off error.
- Check for *soil_rechr_max* equal to 0.0 to avoid divide by 0.0 occurrences. It is highly unusual for *soil_rechr_max* values to equal 0.0.

- Use values of *pref_flow_thrsh* to check if preferential flow storage variables are computed instead of **pref_flow_den** as there is no preferential flow storage when **sat_threshold** is specified equal to 0.0. It is highly unusual for **sat_threshold** to be specified equal to 0.0.
- Compute cascading interflow and Dunnian flow only if they sum to greater than 0.000001 rather than greater than 0.0 to reduce computing tiny cascading flows that are possible due to round-off error.
- When there is unsatisfied PET for swale HRU take the amount of PET first from preferential flow reservoir storage (*pref_flow_stor*) before taking from *slow_stor*. Previously, water was only taken from *slow_stor* to compute *swale_actet*. Variable ssres_stor is set to *slow_stor* + *pref_flow_stor*, previously *ssres_stor* was set to *slow_stor*.
- Add checks for the possibility of **soil_rechr_max_frac** (`PRMS5`) or **soil_rechr_max** (`PRMS4`) = 0.0 to avoid divide by 0.0.

`climateflow` subroutine `precip_form`

- For mixed precipitation event check difference between *tmaxf* and *tminf* for < 0.00001 instead of < 0.000001, if true set value to 0.00001 unless value is < 0, which is an error. This is a rare condition that can occur due to improper values of precipitation adjustment parameters.

`precip_dist2`

- For mixed precipitation event check absolute value of the difference between tmaxf and tminf for < 0.00001 instead of < 0.000001, if true set value to 0.00001 instead of 0.01. This is a rare condition that can occur due to improper values of temperature adjustment parameters.

`frost_date`

- Compute spring and fall frost dates for number of days in the year (365 or 366) instead of always 365, still limit fall frost date to 365.

`soltab`

- Value of *PI* set to ACOS(-1.0D) instead of 3.1415926535898D0 to be consistent with use of *PI* in other modules. This may result in very slight changes in solar radiation computations.

`dynamic_soil_read_param`

- New module with code removed from `dynamic_read_param.f90` that is associated with impervious, DPRST, and soilzone dynamic parameters. Dynamic parameter update messages are written to new file as specified by control parameter **dynamic_soil_param_log_file**.

- If DPRST is computed less than 0.0 and the dynamic DPRST fraction (**dprst_frac**) is specified equal to 0.0 for an HRU any excess storage is added to the gravity reservoir (*slow_stor*) instead of capillary reservoir (*soil_moist*) and *dprst_vol_clos*, *dprst_vol_open*, *dprst_area_max, dprst_area_open_max*, and *dprst_area_clos_max* are set to 0.0 to maintain the water balance.
- If storage in dynamic storage fraction changed to greater than the previous value, adjust *dprst_vol_open_frac*, *dprst_vol_clos_frac*, and *dprst_vol_frac* and any excess storage is added to *slow_stor* and *dprst_vol_open*, *dprst_vol_clos*, *dprst_area_max*, *dprst_area_open_max*, and *dprst_area_clos_max* are set to 0.0.
- If impervious fraction storage (*imperv_stor*) is computed less than 0.0 and the dynamic impervious fraction (**hru_percent_imperv**) is specified equal to 0.0 any excess storage is added to *slow_stor* instead of *soil_moist*.
- If the sum of **hru_percent_imperv** and DPRST fraction (**dprst_frac**) is specified greater than 0.999 an error message is printed, and the simulation stops.
- If **dprst_frac** value is specified greater than 0.0 and **dprst_depth_avg** is specified equal to 0.0 an error message is printed, and the simulation stops.
- If a **soil_rechr_max_frac** value is specified greater than 1.0 it is set so that *soil_rechr_max* is greater than or equal to 0.00001.
- If **soil_moist_max** and/or *soil_rechr_max* is specified less than 0.00001 it is set to 0.00001.
- If impervious fraction is modified *hru_impervstor*, *hru_percent_imperv*, and *hru_imperv* are computed to maintain the water balance.
- Antecedent states for *dprst_stor_hru*, *hru_impervstor*, *ssres_stor*, *basin_ssstor*, *soil_moist*, and *basin_soil_moist* are recomputed as they were previously set at the beginning of the timestep in `prms_time`.

`stream_temp`

- Multiply *humidity_hru* by 0.01 to convert to decimal fraction as it is input as percentage. It is read from CBH File when **humidity_cbh_flag** = 1 and used in a computation of *seg_humid*.

`climate_hru`, `potet_pt` and `potet_pm`

- If **humidity_cbh_flag** = 1 *humidity_hru* values read from the humidity CBH File are used, if specified = 0, **humidity_percent** as specified in the Parameter File is used for humidity computations.

`climate_hru`, `potet_pm`, `potet_pt`, and `stream_temp`

- Humidity CBH Files were not read. This caused potential evapotranspiration (*potet*) in the Penman-Monteith and Priestly-Taylor modules to be computed incorrectly when **humidity_cbh_flag** = 1.

`glacr_melt`

- Initialize some local arrays so that non-glacier HRUs have valid values and values from previous timestep are not retained (*xrawm*, *urawm*, *uraw*, *xraw*, *hraw*, *hrawe*, *rline*, *zraw_av*, *sraw*, *y2dd*).
- Check divisor variable *dv1k* for < 0.0, if found set to ABS(*dv1k*) as a negative value cannot be raised to a floating-point value.

`potet_pan`

- Add error check for values of **hru_pansta** specified equal to 0 or greater than **nevap**.

NEW FUNCTIONALITY

climate modules (`precip_1sta`, `precip_laps`, `xyz_dist`, `ide_dist`, `precip_map`, `precip_dist2`, `climate_hru`, `temp_1sta`, `temp_laps`, `temp_sta`, `temp_map`, and `temp_dist2`)

- Added control parameter **forcing_check_flag** that when specified equal to 1 checks for adjusted *tmax* < *tmin*, *tmax* > 200, and *tmin* < -150 are made. Check for adjusted *tmax* > 200 or *tmin* < -150 issues an error message and the simulation stops. The other checks, print a warning message and the simulation continues. Additionally, adjusted *hru_ppt*, *hru_rain*, and *hru_snow* are checked for values less than 0.0, if detected a warning message is printed and simulation continues. Previously, the simulation would stop if *tminf* is less than -150.0 or *tmaxf* greater than 200.0, now this condition is allowed unless **forcing_check_flag** is specified equal to 1. These checks are made in subroutines `precip_form` for precipitation values and `temp_set` for air temperature values that are found in `climateflow`.

`nhru_summary`

- Added option to allow files to be output in a binary format. These binary files may be 30% or more smaller in size than the `nhru_summary` text files. The files will start with the output variable name in all capital letters with the suffix ".bin" based on **nhruOutBaseFileName**. Specify **write_binary_nhru_flag** equal 1 in the Control File along with the standard `nhru_summary` control parameters. The first line for these files includes the word "Date" followed by the HRU identification numbers as 4-byte integers. For files with yearly values, the remaining lines start with the year as a 4-byte integer followed by **nhru** 8-byte values. For files with monthly values, the remaining lines start with the date as 3 4-byte integers (year month day) followed by **nhru** 4-byte values. For files with daily values, the remaining lines start with the date as 3 4-byte integers (year month day) followed by **nhru** 4-byte values. The following Fortran program illustrates a method to read a daily `nhru_summary` binary file with 128 HRUs and less than 100,000 lines of values. To read yearly values the array read must be declared double precision.

```
program read_nhru_summary_daily_bin_file
implicit none
integer :: year, month, day, file_unit, i, nhru, ios
real, allocatable :: daily_values(:)
integer, allocatable :: hru_ids(:)
character(LEN=4) :: date_string
file_unit = 444
nhru = 128
allocate ( daily_values(nhru), hru_ids(nhru) )
open(file_unit, file=".\output\nhru_recharge.bin", IOSTAT=ios, &
     FORM='UNFORMATTED', ACCESS='STREAM')
read(file_unit) date_string, hru_ids
do i = 1, 99999
  read(file_unit,IOSTAT=ios) year, month, day, daily_values
  if (ios<0) exit
enddo
end program read_nhru_summary_daily_bin_file
```

`stream_temp` and `obs`

- Added code to read **nstreamtemp** stream temperature values (*stream_temp*) from the Data File. These values can be used to replace stream temperature (*seg_tave_water*) for segments identified by **tempIN_segment**.

CBH Files (`call_modules` and `climate_hru`)

- Added capability to specify values for a subset (active HRUs) of the model domain in CBH Files instead of values for every HRU. The new dimension **ncbh** and parameter **cbh_hru_id** are used to specify the subset. Values for inactive HRUs are set to -999.0 for real and -999 for integer values. This is active when **cbh_active_flag** = 1.

`call_modules`

- Added option to not call `snowcomp` or `glacr_melt` using new control parameter **snow_flag** which can reduce execution time and reduce the number of input parameters.

`prms_summary`

- Added csvON_OFF = 3 option that produces a CSV file of all segment outflows as specified by **poi_gage_segment** and **poi_gage_id** and dimension **npoigages** as comma separated values with date tag year-month-day.

`segment_to_hru`

- New module to route selected stream segment outflow to the capillary reservoir of selected HRUs. This option can be useful for terminal streams in areas such as playas and closed basins as well as Karst areas. The HRU identification number to which segment outflow is routed is specified by new parameter **segment_outflow_id**. This option is activated by specifying new control parameter **seg2hru_flag** to 1.

`write_climate_hru`

- Write strings "`tmaxc`" and" `tminc`" when **temp_units** = 1 and "`tmaxf`" and "`tminf`" when **temp_units** = 0 to the headers in temperature CBH Files and changed the output format for values from E12.4 to F10.5 for ease of reading the generated CBH Files written.

`intcp`

- Allow some HRUs to compute evaporation from canopy based on *pan_evap* values when **hru_pansta** value is greater than 0 else use standard calculation. Previously, all HRUs had to use *pan_evap* values and all values of **hru_pansta** had to be specified > 0 when **nevap** specified greater than 0.

`soltab`

- Debug csv files, split up from previous version (output full arrays of *Soltab_sunhrs*, *Soltab_potsw*, *obliquity*, and *Solar_declination* in separate files for **print_debug** = 5: `soltab_sunhrs.csv`, `soltab_potsw.csv`, `obliquity.csv`, `solar_declination.csv`)

DIMENSION, PARAMETER AND VARIABLE CHANGES

Control parameter **cbh_binary_flag** is removed.

cascade_tol

- Default changed from 5 acres to 0 so that all cascades are used for very small HRUs instead of possibly ignored if it is not specified.

New Parameters Added to the Control File

snow_flag

- Flag to indicate if snow and glacier (if active) dynamics are computed (0=no; 1=yes), default = 1.

forcing_check_flag

- Flag to indicate performance of precipitation and temperature checks (0=no; 1=yes).

seg2hru_flag

- Flag to route stream segment outflow to the capillary reservoir of associated HRU (0=no; 1=yes).

cbh_active_flag

- Flag to specify whether to input values in CBH files for a subset of the HRUs, such as only for active HRUs (0=no; 1=yes).

write_binary_nhru_flag

- Flag to specify whether to write nhru_summary values in binary format (0=no; 1=yes).

dynamic_soil_param_log_file

- Pathname of the log file that summarizes dynamic parameter changes for soilzone and land surface related parameters.

bias_adjust_flag

- Adds four differences from previous releases or when **bias_adjust_flag** is specified equal to 0, the default value:
  1. To improve the calculation of precipitation temperature used to calculate the form of precipitation as rain, snow or mixed:
     a. The temperature of rain is based on *tavgc* and *tmax_allrain_c* instead of *tmaxc* and *tmax_allsnow_c* in `snowcomp`.
     b. Precipitation is all rain if *tavgf* >= *tmax_allrain_f* instead of if *tminf* > *tmax_allsnow_f* or *tmaxf* >= *tmax_allrain_f*. The form of rain (rain, snow, or mixed) is done in subroutine `precip_form` in `climateflow`. Note, precipitation is all snow if *tmaxf* <= *tmax_allsnow_f* when **bias_adjust_flag** = 0.
  2. Use offset parameters from minimum air temperature adjustment parameters to adjust maximum air temperatures as it is possible in automated calibration methods maximum air temperatures could be set less than minimum air temperature.
     a. New parameter **tmax_adj_offset** is specified that is added to **tmin_adj** instead of using **tmax_adj**, that is not used when **bias_adjust_flag** = 1.
     b. New parameter **tmax_cbj_adj_offset** added to **tmin_cbh_adj** instead of using **tmax_cbh_adj**, that is not used when **bias_adjust_flag** = 1.
     c. New parameter **tmax_map_adj_offset** added to **tmin_map_adj** instead of using **tmax_cbh_adj**, that is not used when **bias_adjust_flag** = 1.
  3. To allow for persistent snowpacks the previous snowpack water equivalent (*pss*) is set to the antecedent snowpack water equivalent on first Julian day of the water year instead of setting *pss* = 0 when **bias_adjust_flag** = 0 in `snowcomp`.
  4. For mixed precipitation event set the temperature of rain that is added to a snowpack to (*tavgc*+*tmax_allrain_c*)*0.5 instead of (*tmaxc*+*tmax_allsnow_c*)*0.5 when **bias_adjust_flag** = 0 in `snowcomp`. If the computed the temperature of rain is set to 0.0 if computed < 0.0. Note, the temperature of snow is set to *tavgc* when precipitation is all snow and *tminc* + *tmax_allsnow_c**0.5 for mixed events. The temperature of snow is set to 0.0 if computed > 0.0. Temperatures have units of degrees Celsius. These changes were made in `snowcomp`.

New Dimensions and Parameters Added to the Parameter File

ncbh

- New dimension that specifies the number of values specified in CBH Files (active HRUs).

nstreamtemp

- New dimension that specifies the number of stream temperature values specified in the Data File.

segment_outflow_id(**nsegment**)

- Identification number of the HRU that receives outflow from a segment; required when **seg2hru_flag** = 1 and may be helpful for HRUs downslope from terminal streams.

cbh_hru_id(**nhru**)

- HRU identification number for each value in CBH File; required when **cbh_active_flag** = 1 and may be helpful when a model domain has many inactive HRUs to input values for only active HRUs.

tempIN_segment(**nsegment**)

- Index of stream temperature value specified in that Data File that is used to replace computed stream temperature in a segment; required when **stream_temp_flag** = 1 and **nstreamtemp** > 0.

tmax_map_adj_offset(**nmap**,**nmonths**)

- Monthly (January to December) additive adjustment factor to maximum air temperature as an offset from **tmin_map_adj** for each mapped, spatial unit estimated based on slope, aspect, and/or other factors used in module `temp_map` when **bias_adjust_flag** = 1 instead of **tmax_map_adj**.

tmax_adj_offset(**nhru**,**nmonths**)

- Monthly (January to December) additive adjustment to maximum temperature for each HRU as offset from **tmin_adj**, estimated based on slope, aspect, and/or other factors, used in modules `temp_1sta`, `temp_laps`, `temp_dist2`, `ide_dist`, `xyz_dist`, and `temp_sta` when **bias_adjust_flag** = 1 instead of **tmax_adj**.

tmax_cbh_offset(**nhru**,**nmonths**)

- Monthly (January to December) additive adjustment to maximum temperature for each HRU as offset from **tmin_cbh_adj**, used in module `climate_hru` when **bias_adjust_flag** = 1 instead of **tmax_cbh_adj**.

Variable Changes

net_rain(**nhru**)

- The value of *intcp_changeover* is added to *net_rain* to simplify computation of soil infiltration, DPRST, snowpack, and water balance. This means that *net_rain* + *net_snow* is > *net_ppt* when *intcp_changeover* > 0.0.

basin_changeover

- If **cov_type** is changed to bare ground (**cov_type**=0) from another cover type through dynamic parameter input, any canopy storage falls as throughfall. This water was not added to *basin_changeover*.

Variable Removed

basin_cap_up_max

- Basin area-weighted average maximum cascade flow that flows to capillary reservoirs.

New Output Variables

hru_perv_actet(**nhru**)

- Actual evapotranspiration from the capillary reservoir for each HRU.

hru_frac_perv(**nhru**)

- Fraction that is pervious for each HRU. This value can change if **hru_percent_imperv** or **dprst_frac** are input as dynamic parameters.

hru_frac_imperv(**nhru**)

- Fraction that is impervious for each HRU. This value can change if **hru_percent_imperv** or **dprst_frac** are input as dynamic parameters.

hru_frac_dprst(**nhru**)

- Fraction that has DPRST for each HRU. This value can change if **hru_percent_imperv** or **dprst_frac** are input as dynamic parameters.

hru_dunnian_cascadeflow(**nhru**)

- Cascading Dunnian surface runoff from each HRU; output when **cascade_flag** = 1 and **ncascade** > 0. This is computed in `soilzone`.

hru_interflow_cascadeflow(**nhru**)

- Cascading interflow from each HRU. This is computed in `soilzone`.

New Input Variables in the Data File

stream_temp(**nstreamtemp**)

- Stream temperature at each measurement station for use as stream temperature replacement, input in the Data File when **nstreamtemp** > 0.

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Version 5.2.1.1 – December 01, 2023

The `strmflow_character` module was added to compute new variables *seg_area*, *seg_width*, and *seg_velocity* when control parameter **stream_temp_flag** is specified equal to `1`. Binary CBH Files are not supported, do not use control parameter **cbh_binary_flag**.

Modifications that are more than simply code formatting are described below.

- Fix to computation of solar radiation for days where the sun does not rise (polar night), such as in Northern Alaska. Polar night conditions resulted previously in divide by zero in `ddsolrad`, for this condition on any HRU, *swrad* is set to 0.0.
- Some version dates of modules were updated.
- Binary CBH Files are not supported (do not use control parameter **cbh_binary_flag**).
- Use ":" instead of 1 as first dimension of two-dimensional arrays passed as arguments to routine as this is more portable between FORTRAN compilers in `nhru_summary`.

BUG FIXES

`routing`

- Fixed case where **seg_slope** is specified < 0.0000001, the segment velocity was computed incorrectly on first time step for `muskingum_mann`.

`stream_temp`

- Fix to not check *seg_tave_water* < -98.0 and reset *t_o* to *seg_tave_water* as all other cases are correctly caught.
- Added check for *seg_width* <= 0.000001, if true set *shade* and *svi* to 0.0 to avoid divide by zero computing *seg_width*.
- The lateral groundwater and subsurface temperatures had been computed incorrectly; they were based only on the values from a single stream segment as opposed to all segments in the model domain.
- Under specific circumstances, certain segment-based variables (i.e., "*seg_lat*", "*seg_humidity*", etc.) had been reinitialized to a value of zero during the simulation, they now retain the previous values. This change produces a notable improvement in performance of the simulation of "seg_tave_water" and related variables.

`nhru_summary`

- Fixed yearly values computed without inclusion of the last day of the year.

NEW FUNCTIONALITY

`streamflow_character`

- New module that is only called with `stream_temp` is active (control parameter **stream_temp_flag** is specified equal to `1)`. It has code taken from `stream_temp` to compute *seg_width* plus computation of *seg_velocity*, *seg_depth*, and *seg_area*. Computations are based on the methods described in: Moody, John, and Troutman, Brent. (2002). Characterization of the spatial variability of channel morphology. Earth Surface Processes and Landforms. 27. 1251 - 1266. 10.1002/esp.403.

PARAMETER CHANGES

New Parameters read from the Parameter File:

pref_flow_infil_frac

- Fraction of soil infiltration and cascading flow partitioned to preferential-flow storage. Previously, this fraction was set to **pref_flow_den** that also was used to set the water-holding capacity of the preferential-flow reservoir as a fraction of gravity reservoir water-holding capacity (**sat_threshold**). If **pref_flow_infil_frac** is not specified it is set to **pref_flow_den** to provide downward compatibility with existing models.

depth_alpha

- Alpha coefficient in power function for stream segment depth calculation as computed when `stream_temp` is active.

depth_m

- M value in power function for stream segment depth calculation as computed when `stream_temp` is active.

seg_close

- Index of closest segment from elevation and latitude for each a segment when stream_temp is active. If not specified, **seg_close** defaults to the upstream segment.

NEW VARIABLES

`stream_character`

- *seg_area*, *seg_velocity*, *seg_res_time*, and *seg_width*; area, mean velocity, mean residence time, and width of each segment, respectively.

==

Version 5.2.1 – February 08, 2022

Modifications that are more than simply code formatting are described below

- Version dates of modules were updated.
- Dimension **nsnow** moved from `obs` to `call_modules`.
- GSFLOW: variable *hru_storage* computes PRMS storage for GSFLOW mode that does not include groundwater storage.
- Binary CBH Files are opened as FORM=UNFORMATTED and ACCESS=STREAM for both Windows and Linux executables. Previously Windows executables opened with FORM=BINARY.

BUG FIXES

`precip_dist2`

- Parameter **max_psta** was declared as a real instead of integer. This did not affect computations.

`temp_dist2`

- Parameter **max_tsta** was declared as a real instead of integer. This did not affect computations.

`intcp`

- *gain_inches* is now set to the unit water depth in the canopy instead of based on how the water is applied. *gain_inches_hru* is the unit water depth over the HRU.
- *basin_changeover* was declared incorrectly as dimensioned by **nhru** instead of **one**.

`cascade`

- **gw_up_id** was set to a single value of **hru_up_id.** Now all upstream values are used when **hru_segment** is used to define cascading flow (control parameter **cascade_flag** = 2).

`intcp`, `srunoff_smidx`, `srunoff_carea`, and `water_balance`

- The *use_sroff_transfer* flag was used to determine if *net_apply* from `intcp` was set to 1 when the canopy application is read from `water_use_read`, which was set whenever `water_use_read` is active. However, the *use_intcp_transfer* flag is set to 1 only when canopy irrigation is active. This latter flag is now used so that the code is slightly more efficient.

`potet_pm`, `potet_pt`, and `climate_hru`

- **humidity_cbh_flag** (flag to specify to read a CBH file with humidity values) and **humidity_day** (filename of the humidity CBH file) control parameters were ignored.

`potet_pm` and `climate_hru`

- **windspeed_cbh_flag** (flag to specify to read a CBH file with windspeed values) and **windspeed_day** (filename of the windspeed CBH file) control parameters were ignored.

`stream_temp`

- Computation of *seg_tave_lat* is moved before computation of the water temperature at the beginning of the time step. This change may lead to significantly different results from previous versions.

NEW FUNCTIONALITY

`snowcomp`

- The computation of approximate cloud cover as the ratio of measured radiation to potential radiation was based on basin variables, it can be optionally computed based on HRU variables, which could be important for large model domains, when control parameter **snow_cloudcover_flag** is specified equal to 1. The HRU equation is:

orad = *swrad*(*ihru*)**Hru_cossl*(*ihru*)**Soltab_horad_potsw*(*Jday*,*ihru*))/*Soltab_potsw*(*Jday*,*ihru*)

cloud cover = *orad*/*Soltab_horad_potsw*(*Jday*,*ihru*)

- A daily snow albedo time series can be input from a Climate-by-HRU (CBH) file, the CBH filename is specified by control parameter **albedo_day** and is read when control parameter **albedo_cbh_flag** is specified equal to 1.

`climate_hru`

- Added reading of albedo and cloud cover CBH Files.

PARAMETER CHANGES

New Parameters read from the Control File*:*

albedo_cbh_flag

- Flag to indicate if snowpack albedo is read from a CBH File (0=no; 1=yes)

albedo_day

- Filename of snowpack albedo CBH File

snow_cloudcover_flag

- Flag to indicate if approximation of cloud cover for snowpack computations is computed using HRU dimensioned variables (0=no; 1=yes)

cloud_cover_cbh_flag

- Flag to indicate if cloud cover for use in `ccsolrad` is read from a CBH File (0=no; 1=yes)

cloud_cover_day

- Filename of cloud cover CBH File

NEW VARIABLES

`intcp`

- *gain_inches* and *gain_inches_hru* – application water to the canopy as a) depth in canopy and b) depth over the HRU, respectively. Both have units of inches.

`climate_hru`

- *albedo_hru* – Snowpack albedo of each HRU read from CBH File, units of decimal fraction.

- *cloud_cover_cbh* – Cloud cover of each HRU read from CBH File, units of decimal fraction.

`water_use_read`

- *soilzone_gain_hru* – Irrigation added to soilzone as depth over each HRU in units of inches.

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Version 5.2.0 – January 20, 2021

This major release (PRMS version 5.2.0) adds new functionality for a) glacier dynamics (module `glacr_melt` and associated major changes to module enhancements to module `snowcomp`); glacier dynamics and two examples are described in Van Beusekom and Viger (2015), b) The continuous frozen ground (CFGI) dynamics was added, which involved changes to modules `soilzone`, `srunoff_carea`, and `srunoff_smidx`; the CFGI method is described in Mastin (2009), and c) distribution of air-temperature and precipitation on the basis of area-weighted mapping from input datasets, such as a gridded data sets (modules `temp_map` and `precip_map`).

There have been numerous changes to the `stream_temp` module since the previous release to address bugs. These include improved calculations of: 1) stream temperatures from stream flow coming from upstream segments; 2) water temperatures from lateral flows from adjacent land surfaces (i.e. lateral components of flow from adjacent HRUs); and 3) water temperatures due to the daily energy fluxes on the stream segments. This version of the `stream_temp` module will give significantly different simulation results than previous versions of the module. Any modeling work done with previous versions of this module should be redone with this (or subsequent) releases. Minor changes were made to several modules to improve code readability.

Modifications that are more than simply code formatting are described below.

- Initial Condition Files (i.e., Restart Files or antecedent conditions files) generated by previous versions of GSFLOW are not compatible with this version, thus they must be regenerated. Previous versions are not compatible because many basin area-weighted variables from prior versions of Restart Files are not needed to restart a simulation and are no included in the Initial Conditions Files.
- New files are: `prms_constants.f90` (contains constant values that are used by many modules that are used to improve code readability and consistency of numerical constants; some constants are new and others moved from `call_modules.f90` and basin.f90); `glacr_melt.f90` (glacier dynamics module); and `precip_map.f90` and `temp_map.f90` (precipitation and temperature distribution modules, respectively, on the basis of mapping from input file to HRUs).

- Changed how module version dates and descriptions are printed to screen and increased consistency in module declarations.
- Water use information applied in associated PRMS process modules instead of in module `water_use_read`. For example, transfers to/from PRMS lakes are applied in `muskingum_lake` and transfers to/from surface depression storage are applied in `srunoff_smidx` and `srunoff_carea`. The transfers were already applied in `soilzone`, `intcp`, and `gwflow`.
- There have been numerous changes to the `stream_temp` module since the previous release to address bugs. This version of the module will give significantly different simulation results than previous versions. Any modeling work done with previous versions of this module should be redone with this (or subsequent) releases.

BUG FIXES

`dynamic_parameter_read`

- Dynamic parameters soil_moist_max, soil_rechr_max, and soil_rechr_max_frac were ignored.

`muskingum` and `muskingum_mann`

- Restart File was incorrect as the string length of the module name was checked using a different string length.

snowcomp

- Fixed possibility of divide by zero when setting maximum snow-water equivalent value (variable *ai*) and computing the fraction of maximum snow-water equivalent (variable *frac_swe*). The former can happen when the maximum snow-water equivalent threshold (parameter **snarea_thresh**) value is 0.0 on an HRU. The latter can occur when values of *ai* are small (<0.1). variable *ai*).
- Variable *ai* is reset when snowpack disappears instead of every timestep.
- Variable *ai* is saved in the Restart File.
- Variables *scrv*, *pksv*, *pk_den,* and *frac_swe* are reset when snowpack disappears during a timestep.

`stream_temp`

- Improved calculations of stream temperatures from stream flow coming from upstream segments.
- Improved calculations of water temperatures from lateral flows from adjacent land surfaces (i.e. lateral components of flow from adjacent HRUs).
- Improved calculations of water temperature due to the daily energy fluxes on the stream segments.

`mmf.c`

- Removed an extra argument to three usages of routine `fprintf` that caused warning messages to be issued during compilation.

NEW FUNCTIONALITY

New files are: `prms_constants.f90` (contains constant values that are used by many modules that are used to improve code readability and consistency of numerical constants; some constants are new and others moved from `call_modules.f90` and `basin.f90`); `glacr_melt.f90` (glacier dynamics module); `precip_temp_map.f90` (precipitation and temperature distribution modules on the basis of mapping from input file to HRUs).

`prms_constants.f90`

- This file defines constants used by many PRMS Modules. These constants are named to increase readability of the FORTRAN code; they do not affect model input, such as specified in the Parameter and Control Files. For example, the constant FAHRENHEIT is set equal to 0 and CELSIUS is set equal to 1 to use in module code to check the value of parameter **temp_units**, if the user specifies as 0 for Fahrenheit and 1 for Celsius in a Parameter File. Similarly, constants SAND is set equal to 1, LOAM = 2, and CLAY = 3 to use in modules that check the value of parameter **soil_type**. Another example is the named constants *ON* and *OFF* that are set to 1 and 0, respectively. Some values were moved from other files, mostly from files `call_modules.f90` and `basin.f90`.

`precip_map`

- This module distributes precipitation to each HRU using precipitation data specified in a Map File as a time series of gridded or other spatial units using an area-weighted method and a correction factor to account for differences in altitude, spatial variation, topography, and data accuracy between the spatial scale of the values specified in the Map File and HRUs. The module requires daily input, thus, any temporal discrepancies (i.e., the values in the Map File are valid for noon one day to noon of the second day are not considered. Values are assumed to be valid for each full day. The Map File is a text file with each day specified by a date and time (year, month, day, hour, minute, second) followed by **nhru** values in order of HRU 1 through **nhru**. Each value can be separated by a space and/or comma. The values for hour, minute and second are specified as 0. For example, the date and time of 2021/1/20 12:15:00:00 can be specified as: 2021 1 20 12 15 0 0 0. Any number of lines can be used to specify each day. For example, if the HRUs are a grid, one way to specify a day is the date on one line followed by values in a gridded format with the number of lines equal to the number of rows in the grid and the number of values on a line equal to the number of columns in the grid. Each HRU is associated with one or more values in the Map File as a fraction based on an intersection of the HRU map and gridded or other map. Use of this option can increase execution speed by reducing the volume of input read during a simulation for models that would require very large climate-by-HRU (CBH) Files that are typically pre-processed distributions of gridded data. Typically, the source gridded data file is much smaller than a CBH File. Additionally, the module allows for calibration adjustments using parameters. See below and/or in the file `PRMS_tables_5.2.pdf` for a description of the required dimensions and parameters, each are labeled with `precip_map` (dimensions **nmap** and **nmap2hru**, parameters **hru2map_id**, **hru2map_pct**, **map2hru_id**, and **precip_map_adj**)

`temp_map`

- This module distributes maximum and minimum temperatures to each HRU using precipitation data specified in a Map File as a time series of gridded or other spatial units using an area-weighted method and a correction factor to account for differences in altitude, spatial variation, topography, and data accuracy between the spatial scale of the values specified in the Map File and HRUs. The module requires daily input, thus, any temporal discrepancies (i.e., the values in the Map File are valid for noon one day to noon of the second day are not considered. Values are assumed to be valid for each full day. The Map File is a text file with each day specified by a date and time (year, month, day, hour, minute, second) followed by **nhru** values in order of HRU 1 through **nhru**. Each value can be separated by a space and/or comma. The values for hour, minute and second are specified as 0. For example, the date and time of 2021/1/20 12:15:00:00 can be specified as: 2021 1 20 12 15 0 0 0. Any number of lines can be used to specify each day. For example, if the HRUs are a grid, one way to specify a day is the date on one line followed by values in a gridded format with the number of lines equal to the number of rows in the grid and the number of values on a line equal to the number of columns in the grid. Each HRU is associated with one or more values in the Map File as a fraction based on an intersection of the HRU map and gridded or other map. Use of this option can increase execution speed by reducing the volume of input read during a simulation for models that would require very large climate-by-HRU (CBH) Files that are typically pre-processed distributions of gridded data. Typically, the source gridded data file is much smaller than a CBH File. See below and/or in the file **PRMS_tables_5.2.pdf** for a description of the required dimensions and parameters, each are labeled with `precip_map` (dimensions **nmap** and **nmap2hru**, parameters **hru2map_id**, **hru2map_pct**, **map2hru_id**, and **temp_map_adj**)

`glacr_melt`

- This module computes glacier dynamics using three linear reservoirs (snow, firn, ice) with time lapses and ability to advance or retreat according to volume-area scaling. The altitude of HRUs can change due to glacial dynamics on any time step, so climate distribution methods that are based on lapse rates use the altitude computed on the previous time step of glacier HRUs. This affects modules `xyz_dist`, `temp_laps`, `precip_laps`, `temp_1sta`, `temp_dist2`, `ide_dist`, and `basin`. The addition of glacier dynamics required significant changes to the `snowcomp` module. New variables were added for glacier runoff to the stream network and from HRUs. An HRU that is or might become glaciated during a simulation is specified by setting the value of parameter **hru_type** to `4`.

Frozen ground dynamics

- Code was added to the modules `basin`, `water_balance`, `srunoff_smidx`, `srunoff_carea`, and `soilzone` to include the continuous frozen ground index (CFGI) method. This addition did not require a new module.

Irrigation application to the canopy – `intcp`

- A value for parameter **irr_type** is specified for each HRU that is used to select how irrigation water, as input to the `water_use_read` module, is applied within and HRU. The meaning of each **irr_type** value follows. Two options for **irr_type** have been added with this release. The first new option (**irr_type**=3, sprinkler application) applies the specified amount of water across the whole HRU, which allows the specified irrigation water to be applied to the plant canopy and non-covered areas, which allows for interception and throughfall across the HRU. The existing options, **irr_type**=0 and **irr_type**=1, sprinkler and ditch/drip application, respectively, apply the specified irrigation water only to the canopy. For **irr_type** = 1, 2, and 3 the irrigation water is specified as an HRU-area weighted average value. The second new option (**irr_type**=4, living filter application) allows for the irrigation water amount to be specified as the amount of water applied to the plant canopy, i.e., not an HRU-area average value. Note, **irr_type**=2 signals to ignore any specified irrigation water.

Stop Conditions

- ERROR messages issued by modules have been reworded to be more consistent in format. Additionally, in ERROR messages and at the termination of a simulation a value is output. A non-zero value indicates an ERROR was detected in the simulation. The values are output according to the following list:

-4 = read input error
-3 = open output file error
-2 = open input file error
-1 = write output error
0 = no error
1 = control parameter error
2 = variable range error
3 = dimension range error
4 = parameter range error
5 = data file input error
6 = timestep error
7 = air temperature range error
8 = streamflow range error
9 = basin module error
10 = Climate-by-HRU (CBH) input error
11 = Cascade input error
12 = Restart file error
13 = Dynamic parameter error
14 = Water-use error
15 = parameter or variable error
16 = module error
17 = lake error
18 = soilzone error

NEW DIMENSIONS

nmap

- Number of spatial units in mapped climate, used in modules `temp_map` and `precip_map`.

nmap2hru

- Number of intersections between HRUs and spatial units in mapped climate, used in modules `temp_map` and `precip_map`

four

- Number of glacier variables in integer array, fixed at 4, used in module `glacr_melt`.

nglres

- Number of reservoirs in a glacier, fixed at 3, used in module `glacr_melt`.

seven

- Number of glacier variables in real array, fixed at 7, used in module `glacr_melt`.

PARAMETER CHANGES

New Parameters read from the Control File

frozen_flag

- Flag to indicate if continuous frozen ground index simulation is computed (0=no; 1=yes)

glacier_flag

- Flag to indicate if glacier simulation is computed (0=no; 1=yes)

mbInit_flag

- Flag to indicate the method used for initial mass balance of glaciers (0=no optimization; 1=use first year of climate data; 2=constant mass balance gradient above and below equilibrium line altitude (ELA))

stream_temp_shade_flag

- Flag to indicate how shade is used in the `stream_temp` module (0 = compute shade; 1 = specified as a constant)

outputSelectDatesON_OFF

- Switch to indicate if `nhru_summary` output files are generated for a specified set of dates (0=no, output time series on basis of **nhruOut_freq**; 1=yes, specify dates in file specified by **selectDatesFileName**)

selectDatesFileName

- String to define the filename of the set of dates to output values of nhru_summary output files in chronological order with dates specified as YEAR MONTH DAY with a space(s) and/or comma separating YEAR and MONTH and MONTH and DAY (e.g. 1959 09 01)

New Parameters: read from Parameter Files

See the file 'PRMS_tables_5.2.0.pdf' for descriptions of the 16 new parameters related to the simulation of glacier dynamics. These are identified by highlighted red text in the Glacier and frozen ground computations section of Table 1-3.

hru2map_id – used in modules temp_map and precip_map.

- HRU identification number associated with each intersection between the HRU map and grid or other spatial unit map with **nmap2hru** number of values and maximum value **nhru**.

hru2map_pct – used in modules temp_map and precip_map.

- Portion of HRU associated with each intersection between the HRU map and grid or other spatial unit map with **nmap2hru** number of values, expressed as a decimal fraction.

map2hru_id – used in modules temp_map and precip_map.

- Grid or other spatial unit identification number associated with each intersection between the HRU map and grid or other spatial unit map with **nmap2hru** number of values with maximum value **nmap**.

precip_map_adj – used in module precip_map.

- Monthly (January to December) multiplicative adjustment factor to mapped precipitation to account for differences in elevation, and so forth.

tmax_map_adj – used in module temp_map.

- Monthly (January to December) additive adjustment factor to maximum air temperature for each mapped spatial unit estimated on the basis of slope and aspect.

tmin_map_adj – used in module temp_map.

- Monthly (January to December) additive adjustment factor to minimum air temperature for each mapped spatial unit estimated on the basis of slope and aspect.

cfgi_decay – used in frozen ground simulation option.

- Continuous frozen ground index (CFGI) daily decay index, value of 1.0 is no decay.

cfgi_thrshld – used in frozen ground simulation option.

- Continuous frozen ground index (CFGI) threshold value indicating frozen soil.

Updated Parameters read from a Parameter File

hru_type

- A value of 4 specifies that the HRU is or can be glaciated.

adjust_rain and **adjust_snow**

- The maximum suggested value was increased to 3.0. They are used in modules `xyz_dist` and `ide_dist`.

rain_adj

- The maximum suggested value was increased to 10.0. It is used in module `precip_1sta`.

ssr2gw_rate

- The units were corrected to be inches/day and the maximum suggested value increased to 999.0. See description of deprecated parameter **ssrmax_coef** in table 1.3, page 53 of the PRMS documentation report for the formulation of computing gravity drainage with **ssr2gw_rate**. The parameter **ssrmax_coef** was replaced with the constant 1.0, with units of inches.

width_alpha

- The units were corrected to be meters and the maximum suggested value increased to 1000.0 and the default value changed to 1.0. It is used in the `stream_temp` module.

irr_type

- Added two options (3 and 4) for application method of irrigation water for each water-use plant canopy time-series. Values are specified for each HRU with one of the following: 0 = sprinkler method with interception only; 1=ditch/drip method with no interception; 2=ignore; 3=sprinkler across whole HRU with interception and throughfall; and 4=sprinkler method with amount of water applied on the basis of cover density, such as a living filter. Note, for options 1, 2, and 3 the irrigation water is specified as an HRU-area weighted average value as cubic feet per second.

NEW VARIABLES

See the file '**PRMS_tables_5.2.0.pdf**' for descriptions of the 72 new variables related to the glacier dynamics and 3 new variables for frozen ground computations. These are identified by highlighted red text in Glacier and frozen ground computations section of Table 1-5.

`gwflow`

- *lakein_gwflow* – Groundwater flow received from cascading upslope GWRs for each Lake GWR in units of acre-inches.

`basin`

- *hru_elev_ts* – HRU elevation for timestep, which can change for glaciers.

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Version 5.1.0 – May 01, 2020

Modifications that are more than simply code formatting are described below. Parameter Files for example problems were converted to use the new `PRMS5` parameters instead of the equivalent `PRMS4` parameters. Initial Condition Files (i.e., Restart Files or antecedent conditions files) generated by previous versions of PRMS are not compatible with this version, thus they must be regenerated. Note, the simulation time period for the antecedent simulation is written into the file and printed as well as additional variables are now retained.

Modules and utilities

This major release adds new functionality for simulation of stream temperature (module `stream_temp`), and output summary for HRU and segment dimensioned variables optionally can be output in a gridded CSV format, computation of Muskingum routing on the basis of computing the Muskingum routing equation coefficients using the Manning's N equation (module `muskingum_mann`), and soil-water evapotranspiration computed based on the potential evapotranspiration (PET) rate instead of the unsatisfied PET rate as computed in module `soilzone`. This latter change means that models calibrated using previous versions may have significant changes to results as the soil-water evapotranspiration can be greater than previous versions, which affects states and fluxes of the soil zone. Also, corrected major bugs in the `dynamic_param_read` module, where the dynamic parameter time series files were sometimes not being read correctly and the potential evapotranspiration coefficients were being reset every timestep instead of only when a new set of dynamic parameters were available for a given timestep. Note, variable *wind_speed* when specified in the Data File must be specified in units of meters per second (not miles per hour) for use with module `potet_pm_sta`.

BUG FIXES

`dynamic_param_read` and `utils_prms.f90`

- Dynamic parameter files were not always read correctly. The code now verifies that a line beginning with `####` starts each new set of values.

`dynamic_param_read`

- Variables *soil_moist_tot*, *basin_soil_rechr*, and *basin_soil_moist* were not always set correctly; no other computations were affected. Note, these were computed correctly by the soilzone module, thus they were correct at the end of a timestep.
- The potential evapotranspiration coefficients were being reset every timestep instead of only when a new set of dynamic parameters were available for a given timestep.

`cascade`

- Fortran compiler error to pass a function argument to another routine. This was not an error in earlier versions of compilers used to build PRMS.

`climateflow`

- Variable *orad* was always initialized to 0.0 instead of being set by value in the Restart File, if used. This doesn't affect any other computations.

`srunoff_smidx` and `srunoff_carea`

- Variable *hru_imperv_stor* was always initialized to 0.0 instead of being set by value in the Restart File, if used. This omission might have affected some water balance computations for restart simulations.
- Water-use input was not added to variable *infil* if there was also cascading flow.
- A rare, small, water balance issue was found for the conditions that canopy storage exists in an HRU on the day that the transpiration period changes (i.e., a change of growing season) and there is a decrease in canopy density, there is snowmelt, and there is not a mixed precipitation event. The excess canopy storage was added for the computation of soil infiltration and surface runoff. If all these conditions happened, it is likely the water balance for that day and that HRU would be off by very small amount, such as less than 0.003 inches. The amount would depend on the canopy cover density differences and maximum storage capacity in the canopy. This will only happen when the difference between **covden_sum** and **covden_win** is positive, with canopy storage, and snow on the ground at the growing season end, which often people have set as October 1, the old default value for **transp_end** when using module `transp_tindex`. Similarly, it could happen if the difference between **covden_win** and **covden_sum** is positive under the same conditions.

`potet_pm_sta`

- Variable *wind_speed* as specified in the Data File must be specified in units of meters per second, not miles per hour as documentation previously stated in error. This is not a bug in the code, but an error in the documentation.

CHANGES THAT CAN AFFECT SIMULATION RESULTS

`soilzone`

- Values of soil-water evapotranspiration (ET) are computed based on the potential evapotranspiration (PET) rate instead of the unsatisfied ET rate (PET rate less canopy, snowpack, impervious storage, and surface-depression storage ET) when control parameter **soilzone_aet_flag** is specified equal to 1. This change may significantly alter results of existing models compared to using previous versions of PRMS. The change typically would increase soil-water ET and reduce soilzone storage, recharge rate, and groundwater storage and fluxes. If **soilzone_aet_flag** is not specified equal to 1, then soil-water ET is computed as done in previous versions, i.e., based on the unsatisfied PET rate and fraction of the upper zone of the total capillary reservoir water-hold capacity, thus maintaining downward compatibility for existing models. It is recommended that **soilzone_aet_flag** be specified equal to 1 for new models.

- If any lake evaporates at greater than the computed PET rate, then the PET rate is set equal to the lake evaporation rate for the lake HRU and variable *basin_potet* is recomputed. This can occur if **lake_evap_adj** is specified greater than 1.0.

`utils_prms.f90`

- Open statements for binary files must specify UNFORMATTED instead of BINARY for Linux-based computers. This is a code difference between Windows and Unix versions. A second version of `utils_prms.f90`, named `utils_prms_linux.f90` is provided for use on Linux-based computers.

NEW FUNCTIONALITY

`muskingum_mann`

- Specifying control parameter **strmflow_module** to `muskingum_mann` provides an additional method to compute **K_coef** values, which are used along with values of parameter **x_coef** to compute coefficients for the Muskingum streamflow routing method. Values of **K_coef** are computed in `routing.f90` based on the values of new parameters **mann_n**, **seg_length**, **seg_depth**, and **seg_slope**.

$$velocity = (1.0 \div \mathbf{mann\_n}(i)) \times \sqrt{\mathbf{seg\_slope}(i)} \times \mathbf{seg\_depth}(i)^{2/3}$$

$$\mathbf{K\_coef}(i) = \mathbf{seg\_length}(i) \div (velocity \times 60 \times 60)$$

K_coef values computed greater than 24.0 are set to 24.0, values computed less than 0.01 are set to 0.01, and the value for lake HRUs is set to 24.0. Note, **K_coef** values are specified as a parameter when **strmflow_module** is specified as `muskingum`

`snowcomp`

- Snow depletion curves optionally can be specified using an equation on the basis of new parameters **snarea_a**, **snarea_b**, **snarea_c**, and **snarea_d** when control parameter **snarea_curve_flag** is specified equal to 1. Otherwise, the snow depletion curves are specified as in previous versions using parameters **hru_deplcrv** and **snarea_curve**. Each of 11 values of the depletion curve are computed as for each HRU (index i):

$$snarea\_curve(j,i) = (snarea\_a(i) - snarea\_d(i)) \div \left(1 + \left(x^{(snarea\_b(i))} \div snarea\_c(i)\right)\right) + snarea\_d(i)$$

where variable x equals 0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, and 1.0 as index j increments from 1 to 11. Note, **snarea_a** is the minimum value of snowpack water equivalent (SWE) and defaults to 0 and values can have a maximum value of 1.0.

`nhru_summary`

- output summary optionally can be output in a gridded CSV format with number of columns of values specified by control parameter **nhruOutNcol**. If **nhruOutNcol** is specified equal to 0 or not specified each output line contains all **nhru** values as in previous versions.

`strmflow_in_out`

- Parameter **segment_flow_init** applied in routing.f90 to allow initialization of flows in all segments instead of always starting with zero flows, code changes made in `muskingum`, `muskingum_lake`, `muskingum_mann`, and routing.f90.

`dynamic_param_read`

- Control parameter **dynamic_param_log_file** added to allow the name of the log file to be specified rather than hard-coded. This allows multiple simulations to be executed in a single Windows directory as multiple log files can be open when different names are specified in each Control File.

PARAMETER CHANGES

New Control Parameters

soilzone_aet_flag

- Flag to specify whether to compute soil-water evapotranspiration (ET) based on unsatisfied potential ET (PET) (0=compute soil-water ET based on unsatisfied ET; 1=based on PET); set to 0 for downward compatibility of old models though it is recommended setting to 1 for new models.

dynamic_param_log_file

- Specifies the name of the log file written when the `dynamic_param_read` module is active.

nhruOutNcol

- Specifies the number of columns written per line for `nhru_summary` output, which can be used to generate gridded output. If not specified or set to 0, all values for each timestep are written on a single line as in previous versions.

stream_temp_flag

- Flag to activate simulation of stream temperature using the `stream_temp` module (0=off; 1=on).

strmtemp_humidity_flag

- Flag to specify where humidity information is read for use by the `stream_temp` module (0=CBH File specified by control parameter **humidity_day**; 1=parameter **seg_humidity**; 2=Data File with values assigned based on parameter **seg_humidity_sta**).

snarea_curve_flag

- Flag to specify whether to compute snow depletion curves for each HRU using an equation on the basis of new parameters **snarea_a**, **snarea_b**, **snarea_c**, and **snarea_d** when control parameter **snarea_curve_flag** is specified equal to 1. (0=specify snow depletion curves using parameters **hru_deplcrv** and **snarea_curve**; 1=compute snow depletion curves).

Updated Control Parameters

csvON_OFF

- If specified equal to 2, only simulated and measured streamflow pairs are written to PRMS CSV File specified by control parameter **csv_output_file**.

print_debug

- If specified equal to -2, screen output is very limited, and the PRMS water budget file specified by control parameter **model_output_file** is not generated and the `basin_sum` module is not used. Thus, all computed variables unique to `basin_sum` are not available.

`strmflow_module`

- New option: `muskingum_mann`, where Muskingum routing parameter **K_coef** is computed as described above.

Updated Parameters

lake_evap_adj

- Maximum value changed to 1.5 to allow lakes to evaporate at greater than potential evapotranspiration (PET) rate, such as during winter months when lake water temperature may be greater than air temperature.

den_init, **den_max**, **settle_const**

- These snow parameters now have a maximum dimension of **nhru**. Previously, they were scalar values (dimension of **one**).

New Parameters

See the file '**PRMS_tables_5.1.0.pdf**' for descriptions of the 27 new parameters related to the stream temperature module. These are identified by highlighted magenta text in the Stream temperature simulation section of Table 1-3.

ppt_zero_thresh – changes in `climateflow`, `climate_hru`, and `obs`.

- Sets the minimum value for precipitation values specified in the Data File specified by control parameter **data_file** or CBH File specified by control parameter **precip_day**. Precipitation values below this threshold are set to 0.0. Default value is 0.0. An example use case of this functionality is to control for drizzle associated with some downscaled general circulation model climate inputs.

mann_n – added to `routing`.

- Specifies the Manning's roughness coefficient for each segment as a dimensionless value for use by module `muskingum_mann`. Default value is 0.04.

seg_slope – added to `routing`.

- Specifies the surface slope of each segment as approximation for bed slope as a decimal fraction for use by module `muskingum_mann`. Default value is 0.0001.

seg_length – added to `routing`.

- Specifies the length of each segment in meters for use by module `muskingum_mann`. Default value is 1.0.

seg_depth – added to `routing`.

- Specifies the segment depth at bank full of each segment in meters for use by module `muskingum_mann`. Default value is 1.0.

NEW VARIABLES

See the file '**PRMS_tables_5.1.0.pdf**' for descriptions of the 13 new variables related to the stream temperature module. These are identified by highlighted magenta text in Stream temperature simulation section of Table 1-5.

`soilzone`

- *soil_saturated* – set to 1 if capillary zone is saturated by an infiltration event, otherwise set to 0.

SMALL CHANGES THAT DO NOT AFFECT ANY COMPUTATIONS

`muskingum`, `muskingum_lake`, and `routing`

- Parameter **segment_flow_init** applied in `routing` and so code is not duplicated in Muskingum modules.

`climateflow`

- Add variables *basin_potsw* and *basin_humidity to* the Restart File.

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Version 5.0.0 – May 30, 2019 - doi:10.5066/P91FBZOB

This major release adds new functionality for:

- input of dynamic parameters and water use data;
- Muskingum streamflow routing with simulation of lakes;
- output of subbasin, stream segment, and basin variables to Comma-Separated-Variable (CSV) files by activating modules `nsub_summary`, `nsegment_summary`, and/or `basin_summary`;
- an option to compute potential evapotranspiration by using the Penman-Monteith formulation on the basis of specified windspeed and humidity data in the Data File; and
- distribution of air temperature on the basis of specified minimum and maximum data in the Data File.

Also, corrected major bugs in the `potet_pm` and `potet_pt` modules and minor bugs in the `soilzone` and `gwflow` modules. See "**Update of PRMS PET modules.pdf**" file in the '`doc`' subdirectory for corrections to PRMS-IV documentation report regarding the potential evapotranspiration modules.

Restart Files generated by previous versions are not compatible with the current version, thus they must be regenerated. The simulation time period for the antecedent simulation is written into the file and printed after it is read.

Several PRMS parameters are deprecated and replaced by new parameters that were added to facilitate automated model calibration. Most of the deprecated parameters were codependent with other parameters and were specified as a depth per unit area. The new parameters are specified as a fraction of or offset to the related deprecated parameter. To use the new parameters, specify **model_mode** as `PRMS5`. To retain downward compatibility, to use the deprecated parameters, specify **model_mode** as `PRMS`. Parameter Files for example problems were converted to use the new PRMS5 parameters instead of the equivalent PRMS4 parameters. A new module was added to facilitate adding the new parameters to an existing model. To activate this module, specify control parameter **model_mode** as `CONVERT` to produce a file of the new parameters. Similarly, specifying **model_mode** as `CONVERT4` will produce a file of the old parameters based on a model using the new parameters. Once the new parameters are added to a Parameter File it is recommended the old parameters be removed.

See the file '**tm6b8_PRMS_enhancements.pdf**' (Regan and LaFontaine, 2017) in the '`doc`' subdirectory for documentation on the dynamic parameters; water-use, lake simulation, and HRU summary options.

INITIAL CONDITIONS FILES

- Initial Condition Files made with previous PRMS versions are not compatible with this version; thus, they must be regenerated. The simulation time period for the antecedent simulation is written into the file and printed when used. The new files are about 75 percent smaller as only variables needed to maintain a water balance are stored. Modules with fewer values saved are: `snowcomp`, `soilzone`, `srunoff_smidx`, `srunoff_carea`, `routing`, `gwflow`, `intcp`, and `muskingum`.

- Restriction for changing to or from modules `potet_pt`, `potet_pm`, `potet_pm_sta`, `ide_dist`, and `xyz_dist` for restart simulations has been removed.
- Restriction for changing the content of Data File(s) for restart simulations has been removed.
- Options that cannot change for a restart simulation include: a) surface depression storage simulation option; b) cascading flow simulation option; c) dimensions **nhru**, **nssr**, **ngw**, **nsegment**, **nhrucell**, **nlake**; and d) the model mode (`PRMS` or `PRMS5`); and e) use of modules `temp_1sta`, `temp_laps`, `temp_dist2`, `potet_pan`, `transp_tindex`.
- Various states can be updated for a restart simulation by using new options as specified by control parameter **init_vars_from_file** (0 = do not read initial value parameters; 1 = read all initial value parameters; 2 = read **dprst_frac_init**, **snowpack_init**, **segment_flow_init**, **elevlake_init**, **gwstor_init**, (**soil_rechr_init**, **soil_moist_init**, **ssstor_init** for **model_mode** = `PRMS`) or (**soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac** for **model_mode** = `PRMS5`); 3 = read **snowpack_init**; 4 = read **elevlake_init**; 5 = read (**soil_rechr_init_frac**, **soil_moist_init_frac**, **ssstor_init_frac** for **model_mode** = `PRMS5`); 6 = read **gwstor_init**; 7 = read **dprst_frac_init**). Options 2 and 3 could be used, for example, to update the snowpack based on observed values of snowpack water equivalent by restarting a simulation and specifying values for **snowpack_init** to reflect an observed or model snow water equivalent data set.

BUG FIXES

`snowcomp`

- When a snowpack is melting and there is a new snowfall, the code saves the point on the depletion curve (variable *snowcov_areasv*) and then depletes the snowpack from **snarea_curve**(11,k) over the subsequent time steps until the snow cover is less than or equal to *snowcov_areasv* on the basis of linear interpolation. See Figure 1-4, page 97 of the PRMS-IV documentation report (TM6-B7, Markstrom and others, 2015) for a depiction of how to compute snow-water equivalent (SWE) using a depletion curve after a secondary snowfall. However, *snowcov_areasv* was set to **snarea_curve**(11,k), the maximum value of a snow depletion curve, instead of current value of *snowcov_area*. This issue was fixed. This change can affect results of the snowpack depletion for secondary snowfalls as depletion begins at the maximum value of the depletion curve instead of returning to the point of departure from the depletion curve from which it

was melting prior to the snowfall. Thus, there will be no change for many simulations, but noticeable changes could occur for some simulations.
- Variable *frac_swe* was not computed for all time steps, this was corrected, and the variables were changed to single precision; this change did not affect other computations.
- Variable *tcal* was not reset to 0.0 for all time steps, which might have meant values were carried over after a snowpack melted, this was corrected; this change did not affect other computations.
- Initial snow cover area was computed incorrectly, this would only affect the first timestep.

`temp_dist2`

- Values for parameter **tmax_adj** and **tmin_adj** were not read from the Parameter File and were likely set to zero or very small values.

`climate_hru`

- Corrected check that looked for first simulation time step in CBH Files that failed if simulation start month and year were earlier than the first date in the CBH File.

`soilzone`

- Parameters **soil_moist_max**, **soil_rechr_max**, and **soil_rechr_max_frac** could have values specified equal to 0, which would cause divide by zero in several equations. To prevent divide by zeros and to allow for some minimum storage in capillary reservoirs to receive cascading flow, the code was modified to issue an error if values for these parameters are specified less than 0.00001. If control parameter **parameter_check_flag** is specified equal to 0, a warning message is issued, and the value is set to 0.00001.
- Parameters **slowcoef_lin**, **slowcoef_sq**, **fastcoef_lin**, and **fastcoef_sq** can have values specified equal to 0. However, under rare conditions, doing so could cause a divide by zero. The code was modified to trap for possible divide by zero and ensure a valid value is computed for interflow. Also, for some combinations of these parameters and a large gravity storage value it was possible to compute very small negative values of interflow due to floating point precision round off error. The code was modified to set any computed negative values of interflow to 0.

`prms_summary`

- If values for optional parameter **poi_gage_segment** were greater than 999999 values in the header row were truncated at 7 digits. This has been corrected. Additionally, the format of the output values was changed from a fixed 10-digit exponential to values with 4 decimal places with as many values to the left of the decimal places as required.

`routing`

- Values for solar radiation and potential evapotranspiration could be computed incorrectly for segments that did not have associated HRUs, this has been fixed to assign values from closest upstream segment.

CHANGES THAT CAN AFFECT SIMULATION RESULTS

`snowcomp`

- For calculations of emissivity and energy related to convection or condensation, the code checks if there is precipitation on an HRU instead of anywhere in the model domain to adjust these values based on precipitation and cloud cover.
- Snow depletion curves must be specified, previous versions allowed snow depletion curves to not be specified when dimension **ndepl** was specified equal to 0.
- Several checks for small negative round-off errors were removed to reduce bias in round-off error. Thus, it is possible for some variables to have very small negative values. This should be a rare occurrence.

`soilzone`

- Values of **ssr2gw_rate** specified less than 0.000001 were treated as 0. Now, all **ssr2gw_rate** values > 0.0 are used to compute gravity drainage. In general, specifying parameter values < 0.000001 are going to produce results within or below the limits of floating-point precision, so they will be adding more noise and increased execution time than useful results.

`intcp`

- Previously, if there was canopy storage at the changeover of a transpiration period (winter to summer or summer to winter) and the canopy could not hold the antecedent water content, this water was added to *net_rain*. This water is now kept track of in variables *intcp_changeover* and *basin_changeover* and added in the same manner as *net_rain* in the `srunoff_smidx` and `srunoff_carea` modules. Overall results don't change, except that *net_rain* is consistent with the total amount of precipitation.

NEW FUNCTIONALITY

`dynamic_param_read`

- Read and makes available dynamic parameters by HRU from pre-processed files.
- Dynamic parameters include those that specify impervious surface fraction and storage capacity; storage capacity of the capillary and recharge reservoirs of the soil zone; total surface-depression storage and open surface-depression fractions, depth, pervious and impervious surface-runoff capture fraction, and storage threshold for open depressions to spill; canopy type, density, and storage capacity; plant transpiration period; and solar radiation transmission and potential evapotranspiration (ET) computation coefficients.

`water_use_read`

- Read and makes available water-use data (diversions and gains) from pre-processed files.
- Water can be withdrawn from five sources: (1) stream segment flow, (2) groundwater reservoir storage, (3) open surface-depression storage, (4) external locations, and (5) lake storage. Source water can be transferred to any of eight destinations: (1) stream segments, (2) groundwater reservoir storage, (3) open surface-depression storage, (4) external locations, (5) lake storage, (6) capillary reservoir storage, (7) internal consumptive-use locations, and (8) plant canopy storage. Water transfers can be any source/destination combination. Multiple transfers can originate from each source, and each destination can receive water from multiple sources.
- Modules `intcp`, `soilzone`, `srunoff_smidx`, `srunoff_carea`, `gwflow`, `strmflow_in_out`, `muskingum`, and `muskingum_lake` were modified to account for water-use transfers.

`potet_pm_sta`

- Computes the potential evapotranspiration by using the Penman-Monteith formulation (Penman, 1948; Monteith, 1965) using specified windspeed and humidity in the Data File.

`muskingum_lake`

- Routes water between segments in the system using Muskingum routing and on-channel water body storage and flow routing.

`temp_sta`

- Similar temperature distribution to `temp_1sta` except that no adjustment is made using lapse rates. The value of the associated temperature from a station by parameter **hru_tsta** is adjusted using parameters **tmax_adj** and **tmin_adj**.

`nhru_summary`

- Added output yearly total and mean yearly time series on the basis of control parameter **nhruout_freq** (1 = daily, 2 = monthly, 3 = both, 4 = mean monthly, 5 = mean yearly, 6 = yearly total); daily files have the suffix .csv; monthly files have the suffix _monthly.csv; mean monthly have the suffix _meanmonthly.csv; and mean yearly and yearly total have the suffix _yearly.csv.
- Added the option to output of NHM HRU identification number (parameter **nhm_id**) to CSV files when control parameter **nhruOutON_OFF** is specified equal to 2.
- Added the capability to output integer variables in addition to real and double variables.
- Added the option to output using different formats using new control parameter **nhruOut_format** (1 = scientific notation with 4 significant digits (default); 2 = 2 decimal places; 3 = 3 decimal places; 4 = 4 decimal places; 5 = 5 decimal places).
- Parameter **prms_warmup** is now specified in the Control File.

`nsub_summary`

- Summary output module that operates similar to `nhru_summary` and with similar control parameters, except that it is used to write values of variables dimensioned with **nsub** and variables dimensioned with the value of **nhru** when parameter **hru_subbasin** is specified to separate CSV files at daily, monthly, mean monthly, mean yearly, and yearly total time steps when control parameter **nsubOutON_OFF** is specified equal to 1.
- Added the capability to output integer variables in addition to real and double variables.
- Added the new control parameter **nsubOut_format** for outputting different number formats (1 = scientific notation with 4 significant digits (default); 2 = 2 decimal places; 3 = 3 decimal places; 4 = 4 decimal places; 5 = 5 decimal places).

`nsegment_summary`

- New summary output module that operates similarly to `nhru_summary` and with similar control parameters except that it is used to write values of variables dimensioned with **nsegment** to separate CSV files at daily, monthly, mean monthly, mean yearly, and yearly total time steps when control parameter **nsegmentOutON_OFF** is specified equal to 1.
- Added the new control parameter **nsegmentOut_format** for outputting different number formats (1 = scientific notation with 4 significant digits (default); 2 = 2 decimal places; 3 = 3 decimal places; 4 = 4 decimal places; 5 = 5 decimal places).

`basin_summary`

- New summary output module that operates like `nhru_summary`, with similar control parameters, except that it is used to write values of variables dimensioned with **one** to separate CSV Files at daily, monthly, mean monthly, mean yearly, and yearly total time steps when control parameter **basinOutON_OFF** is specified equal to 1.

`map_results`

- Parameter **prms_warmup** is now specified in the Control File.

`potet_pt`, `potet_pm`, and `potet_pm_sta`

- Allows humidity data to be specified using new parameter **humidity_percent** that has maximum dimensions nhru by **nmonths** as an alternative to specifying humidity in a CBH file. Note, previous versions of the `potet_pt` module did not require humidity data.

`cascade`

- Parameter **hru_segment** can now be used to specify simple one-to-one HRU to stream segment cascade paths instead of specifying all cascade parameters with **cascade_flag** set equal to 2. This option assumes **ncascade** = **ncascdgw** = **nhru** and indicates that parameters **hru_up_id**, **hru_strmseg_down_id**, **hru_down_id**, **hru_pct_up**, **gw_up_id**,

gw_strmseg_down_id, **gw_down_id**, **gw_pct_up**, **cascade_tol**, **cascade_flg**, and **circle_switch** are not specified.

`convert_params`

- Produces an output file of replacement parameters added to facilitate calibration efforts. To activate this module, specify control parameter **model_mode** as CONVERT to produce a file of the new parameters (**tmax_allrain_offset**, **soil_rechr_max_frac**, **soil_rechr_init_frac**, **soil_moist_init_frac**, and **ssstor_init_frac**). Similarly, specifying **model_mode** as CONVERT4 will produce a file of the old parameters (**tmax_allrain**, **soil_rechr_max**, **soil_rechr_init**, **soil_moist_init**, and **ssstor_init**) based on a model using the new parameters.

Temperature modules

- To make a consistent check for valid temperature ranges the constants *MAXTEMP* (value = 200.0) and *MINTEMP* (value = -150) were added to `basin`. Distributed values are compared to these values to determine if they are "valid". Values outside this range are treated as missing values. Previously, some modules used the range 150.0 to –99.0.

MODULE REMOVED

`strmflow_lake`

- This module (files `strmflow_lake.f90` and `lake_route.f90`) was replaced by the `muskingum_lake` module with all functionality retained in the new module, which includes routing of streamflow using the Muskingum method.

PARAMETER CHANGES

Notes: there are several ways to specify parameters. Traditionally, a single value is specified per line. However, multiple values can be specified per line if fewer than 12,000 characters are specified and there are no trailing blanks. This might be useful to specify a parameter as a grid of values as **ncol**,**nrow** with the upper left value specified for column 1 row 1 and the bottom right value specified for column **ncol**, row **nrow**. See the section of flexible dimension option described below under release version 4.0.1 for a simplified method of specifying parameters with constant values for any dimension of a parameter.

print_debug

- If specified equal to -2 screen output is very limited and the water budget file specified by control parameter **model_output_file** is not generated and the `basin_sum` module is not used. Thus, all computed variables unique to `basin_sum` are not available.

prms_warmup

- This parameter is now a Control Parameter to allow it to be changed more easily. If specified in the Parameter File, it is ignored. This parameter is used in `nhru_summary`, map_results, nsub_summary, nsegment_summary, and basin_summary to designate a portion of a simulation to not include in the output file(s) for these modules.

gw_seep_coef

- The dimension is now **ngw** instead of **nlake**.

humidity_percent

- This new parameter can be used as an alternative to specification of humidity in a CBH file for modules potet_pt, potet_pm, and potet_pm_sta. It has maximum dimensions **nhru** by **nmonths**.

obsout_segment

- This new parameter is used to specify a replacement flow for outflow of a segment. This is like **obsin_segment** that can be used to specify a replacement flow for the inflow to a segment. Both parameters can be used with modules strmflow_in_out, muskingum, and muskingum_lake, which are available in PRMS or PRMS5 simulation modes. Replacement flows are specified in the Data File and used to assign measured flows to segments instead of the simulated flow. Use of replacement flows breaks conservation of mass but might be useful to set flows below a managed water body.

segment_type

- Specifies type of segment (0 = normal; 1 = headwater; 2 = lake; 3 = replacement flow; 4 = inbound to nation; 5 = outbound from nation; 6 = inbound to region; 7 = outbound from region; 8 = drains to ocean; 9 = sink (terminus to soil); 10 = inbound from Great Lakes; 11 = outbound to Great Lakes; 12 = ephemeral; + 100 user updated; 1000 user virtual segment 100 = user normal; 101 - 108 = not used; 109 sink. This parameter can be used with modules strmflow_in_out, muskingum, and muskingum_lake, with the sole purpose of accumulating total flows for each segment type.

Parameters used when model_mode = PRMS5

tmax_allrain_offset	Equals old parameter tmax_allrain – tmax_allsnow
soil_rechr_max_frac	Equals old parameter **soil_rechr_max** / **soil_moist_max**
soil_rechr_init_frac	Equals old parameter **soil_rechr_init** / **soil_rechr_max**
soil_moist_init_frac	Equals old parameter **soil_moist_init** / **soil_moist_max**
ssstor_init_frac	Equals old parameter **ssstor_init** / *sat_threshold*
sro_to_dprst_perv	Equals old parameter **sro_to_dprst**
dprst_frac	Equals old parameter **dprst_frac_hru**

Parameters used when model_mode = PRMS

tmax_allrain Replaced by **tmax_allrain_offset**

soil_rechr_max Replaced by **soil_rechr_max_frac**

soil_rechr_init Replaced by **soil_rechr_init_frac**

soil_moist_init Replaced by **soil_moist_init_frac**

ssstor_init_init Replaced by **soil_moist_init_frac**

sro_to_dprst Name change to **sro_to_dprst_perv**

dprst_area or **dprst_frac_hru** Replaced by **dprst_frac**

NEW VARIABLES

`strmflow_in_out`, `muskingum`, and `muskingum_lake`

- Added support for additional segment types using the parameter **segment_type** that provides output by category. These are *flow_to_lakes*, *flow_to_ocean*, *flow_to_great_lakes*, *flow_out_region*, *flow_out_NHM*, *flow_in_region*, *flow_terminus*, *flow_in_nation*, *flow_headwater*, *flow_in_great_lakes*, *flow_replacement*.

`intcp`

- *intcp_changeover* and *basin_changeover*

REMOVED VARIABLES

- *cascade_interflow*, *cascade_dunnianflow*, *interflow_max*, *cpr_stor_frac*, *pfr_stor_frac*, *gvr_stor_frac*, *soil_moist_frac*, *soil_rechr_ratio*, *snowevap_aet_frac*, *perv_avail_et*, and *cap_upflow_max*.

SMALL CHANGES THAT DO NOT AFFECT ANY COMPUTATIONS

Determination of Muskingum routing variables moved from source file `muskingum.f90` to `routing.f90` so that the `muskingum` and `muskingum_lake` modules could share the same code.

PRMS UTILITIES

- If an error is encountered reading a Parameter File an error message is issued and the file is no longer read instead of trying to continue reading the file.
- The delimiter between specification of multiple values on a line in a Parameter File was changed from a comma to a space. Trailing blanks cannot be specified on a line as this produces a read error.
- The end of a line for parameter values is determined by either a new line or null character instead of just a new line.
- Possible security issues addressed related mostly to buffer overflow and underflow.

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Version 4.0.3 – May 05, 2017

This release corrected major bugs in the `potet_pm` and `potet_pt` modules and minor bugs in the `soilzone` and `gwflow` modules. Screen and Model Output File output updated for readability and output of additional information. See the updated tables for updates to parameters, variables, modules, and dimensions at:
ftp://brrftp.cr.usgs.gov/pub/mows/software/prms/4.0.3/PRMS_tableUpdates_4.0.3.pdf

BUG FIXES – by module:

`snowcomp`

- When a snowpack is melting and there is a new snowfall, the code is supposed to save the point on the depletion curve (variable *snowcov_areasv*) and then deplete the snowpack from **snarea_curve**(11,k) over the subsequent time steps until the snow covered area is less than or equal to *snowcov_areasv* on the basis of linear interpolation. See Figure 1-4, page 97 of the PRMS-IV documentation report (TM6-B7, Markstrom and others, 2015) for a depiction of how the code was supposed to compute snow-water equivalent (SWE) using a depletion curve after a secondary snowfall. However, *snowcov_areasv* was set to **snarea_curve**(11,k), the maximum value of a snow depletion curve. This fix can change results of the snowpack depletion for secondary snowfalls as depletion begins at the maximum value of the depletion curve instead of returning to the point of departure from the depletion curve from which it was melting prior to the snowfall. Thus, there will be no change for many snowpacks, but, noticeable change to results for some. Variable *frac_swe* was not computed for all time steps, this was corrected, and the variables was changed to single precision; this change did not affect other computations.

`potet_pt`

- The computation of the net long wave radiation was corrected.

`potet_pm`

- The computation of the net long wave and net radiation coefficients used to compute potential ET were corrected.

`srunoff`

- The computation of pervious and impervious capture of pervious and impervious surface runoff into depressions did not account for the fraction of pervious and impervious to compute actual inflow, which lead to the possibility of excess water to the stream network.

`muskingum`

- If **K_coef** was set < 1.0, it was possible to get a divide by 0 under rare conditions, this was corrected.

`temp_dist2`

- Values for parameter **tmax_adj** and **tmin_adj** were not read from the Parameter File and were likely set to zero or very small values.

`soilzone`

- Changed declared dimensions from **nhru** to **one** for variables *basin_cpr_stor_frac*, *basin_gvr_stor_frac*, *basin_pfr_stor_frac*, *basin_soil_lower_stor_frac*, *basin_soil_rechr_stor_frac*, and *basin_sz_stor_frac*. This change does not affect any computations but could cause unpredictable results for output of these variables in statvar and animation files and runtime graphs.
- Computation of *basin_pfr_stor_frac* was computed incorrectly using *pref_flow_stor* instead of *pfr_stor_frac*. This does not affect any other computations.

`gwflow`

- The determination of whether to add storage on the basis of the value of **gwstor_minarea** is done after adding recharge instead of before.

`basin`

- If an HRU had open and closed surface-depression storage portions, computations were incorrect; this was corrected.

SMALL CHANGES THAT DO NOT AFFECT ANY COMPUTATIONS

`call_modules`

- Updated output to screen and to the model output file for improved readability and added output of the Parameter File name.

`cascade`

- Removed checks for specification of farfield flow as farfield computations are no longer supported.

`subbasin`

- Changed units in variable descriptions for *subinc_wb* and *subinc_deltastor* from cfs to inches.

`map_results`

- Messages for incomplete or excess accounting for mapping between HRU map and target map includes more information.

`basin`

- Summary statistics for areal portions and date and times reformatted.

NEW FUNCTIONALITY

`nhru_summary`

- Added output yearly total and mean yearly time series on the basis of control parameter **nhruout_freq** (1 = daily, 2 = monthly, 3 = both, 4 = mean monthly, 5 = mean yearly, 6 = yearly total); daily files have the suffix `.csv`; monthly files have the suffix `_monthly.csv`; mean monthly have the suffix `_meanmonthly.csv`; and mean yearly and yearly total have the suffix `_yearly.csv`.

NEW VARIABLES

- Added variable *basin_swrad*, which is set equal to basin_potsw. This change impacts modules `ccsolrad`, `ddsolrad`, `climate_hru`, and `climateflow`.
- Added subbasin variables: *subinc_rain*, *subinc_snow*, *subinc_stor*, *subinc_recharge*, *subinc_szstor_frac*, and *subinc_capstor_frac*.
- Added `basin_sum` variables: *basin_swrad_yr*, *basin_swrad_tot*, and *basin_swrad_mo*, which are added to summaries in the **model_output_file** on the basis of selected print options.

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Version 4.0.2 – July 29, 2016

This release added new parameters and variables, corrected bugs, added more checks for valid input values, included general code clean up, mostly to reduce mixed floating-point computations by changing some variables to double precision, some to single precision, and added FORTRAN intrinsic functions to convert variables prior to mixed-precision computations. Additional information about input and output files and simulation period are printed to the screen. See the updated tables for updates to parameters, variables, modules, and dimensions at:
ftp://brrftp.cr.usgs.gov/pub/mows/software/prms/4.0.2/PRMS_tableUpdates_4.0.2.pdf

BUG FIXES

`potet_pt`

- The code incorrectly used the value of the average HRU air temperature in degrees Fahrenheit when it was supposed to be in degrees Celsius in one equation. The equation is correct in the PRMS-IV documentation report.

`potet_pm`

- The equation is different from the PRMS-IV documentation report.

`potet_hs`

- The kt coefficient was first being computed each day using an equation based on average temperature as described in https://www.zohrabsamani.com/research_material/files/Hargreaves-samani.pdf. Then this value was multiplied by the **hs_krs** parameter. Now, only the **hs_krs** parameter is used in the Hargreaves-Samani equation, which matches the PRMS-IV documentation. The kt coefficient equation can be used to estimate the **hs_krs** parameter: *coef_kt* = 0.00185*(*temp_dif***2) – 0.0433**temp_dif* + 0.4023, where *temp_dif* is the difference between the HRU maximum and minimum temperature in units of degrees Celsius.

`precip_laps`

- Arrays for parameters **rain_adj_lapse** and **snow_adj_lapse** were not allocated causing application to fail.

`routing`

- Variables *seginc_potet*, *seginc_gwflow*, *seginc_ssflow*, *seginc_sroff*, *seginc_swrad*, *seg_gwflow*, seg_*ssflow*, *and seg_sroff* were computed if the cascading flow option was active, which was an error if parameter **hru_segment** was not specified. These variables are not computed if the cascading flow option is active.
- The value of *seg_lateral_inflow* was not set correctly when the cascading flow option was active; it is now set to *strm_seg_in*.

`subbasin`

- Subbasin storage did not include surface-depression or lake storage.

`climate_hru`

- Variable *basin_obs_ppt* was set to 0.0 if precipitation values are not input in a CBH file; thus, an error occurred if parameter **precip_module** was not specified equal to `climate_hru`.

`map_results`

- Yearly output was not computed when parameter **mapvars_freq** = 5.
- Corrected IF blocks that determine whether or not parameters **gvr_cell_pct** and **gvr_hru_id** were needed; **gvr_cell_pct** needed when **nhrucell** not equal **ngwcell** and **gvr_hru_id** needed when **nhru** not equal **nhrucell**.

`gwflow`

- Variable *basin_lake_seepage* was computed incorrectly by using incorrect values of **hru_area**.

`basin_sum`

- The value of the yearly observed streamflow or monthly value of computed basin streamflow and monthly observed streamflow was not printed for **print_type** = 2.
- Detailed output did not have the right line length, thus missing a value.
- Yearly detailed output now includes evaporation for lakes and interception storage.

`ide_dist`

- Computations of inverse distance and elevation allowed to be less than 0 for precipitation computations so that they are consistent with computations for temperature computations.

`srunoff_smidx` and `srunoff_carea`

- Variable *contrib_fraction* was declared as dimension **one** and data type double when it should be dimension **nhru** and data type single. This error could have caused memory problems if the variable was output in a Statistics Variable (statvar) or Animation File, or using the PRMS GUI runtime plots, but would not affect any computations.

`soilzone`

- Computation of variable *soil_lower_ratio* was set incorrectly to *soil_moist*/**soil_moist_max** instead of *soil_lower*/*soil_lower_stor_max* and values of *soil_lower_ratio* for lake and inactive HRUs were not initialized to 0. No other computations are affected.
- In the `compute_soilmoist` routine, the check for infiltration water in excess of **soil_moist_max** minus *soil_to_gw* (local variable *excs*) was > *infil* should have been a check for *excs>infil*perv_frac* as *excs* is computed for the whole HRU area and *infil* for only the pervious area on an HRU; this condition was not likely to have occurred.
- Make sure any flow from gravity to preferential-flow reservoirs is set to 0 or current value (previous versions could have used value from previous HRU if current HRU in loop does not have preferential flow reservoir).

`basin`

- Corrected code to ensure a divide by zero is not permitted for the condition that there are closed depressions but not open depressions; that is, if any values for parameter **dprst_frac_open** are specified = 0.
- If the first value of parameter **dprst_area** was specified < 0 or not included in the Parameter File, the values of **dprst_frac_hru** (default value = 0) were ignored if specified. Thus, if **dprst_frac_hru** was not included in the Parameter File no surface-depression storage would be simulated; this check should have been reversed. Use of parameter **dprst_area** is now deprecated, so users should now use **dprst_frac_hru** and specify values >= 0. The default value of **dprst_frac_hru** is now -1.0.

`snowcomp`

- Added check to be sure *snowcov_area* is not equal to zero when *pkwater_equiv* is greater than 0. This would be very rare and only possible when the second value of a snow-depletion curve was specified equal to zero.
- Checks were added to be sure *pkwater_equiv* is set to 0.0 if it is computed as a very small negative value, which would be very rare.
- Added check for when *pkwater_equiv* < 1.0E-10 and *snowcov_area* > 0; if true, set *snowcov_area* to 0. This is possible when the energy is enough to melt the snowpack on the previous time step. This bug affected computations for impervious and surface-depression storage evaporation for days without snow and snow depletion curves that specified snow-covered area exists when the snow-water equivalent is equal 0.
- In calin function, *snowcov_area* was set to 0 when it should not be because it is the snow cover after adding precipitation and before any melt or sublimation; this condition affects computations for impervious and surface-depression storage evaporation for days with snow.
- If snowpack exists and the snowpack density (*pk_den*) <= 0, be sure *pk_den* and the snowpack depth (*pk_depth*) have a value based on parameter **den_max** in run function and `calin` function; this condition would be rare.
- In routine `calin`, added check for the value of *freeh2o* – *pwcap* > *pkwater_equiv*; if so, use the value of *pkwater_equiv*. This condition would be rare.
- In routine `calin`, the local variable *apk_ice* did not have a value if *snowcov_area* <= 0; if true, it is set to 0. This condition would be rare.

`water_balance`

- Full array for *hru_sroffp* and *hru_sroffi* instead of HRU value printed for water-budget issue for **srunoff** with cascades active.
- Variable *soil_to_ssr* was not included in HRU **soilzone** water-budget computation. This variable is needed because the variable *cap_waterin*, actual water into capillary reservoir, replaced *cap_water_maxin*, the maximum potential water into the capillary reservoir.

UPDATES THAT MIGHT PRODUCE SLIGHT CHANGES IN ASSOCIATED COMPUTATIONS – general:

- Some single-precision variables were changed to double-precision variables and vice versa; also, most modules now use FORTRAN intrinsic functions to explicitly designate mixed-precision computations. These changes are intended to limit the possibilities of different results on different computers and compilers, to provide more consistent floating-point comparisons, and to have more consistent round-off issues. These updates could change memory requirements and execution time very slightly. Modules affected: `obs`, `cascade`, `ccsolrad`, `ddsolrad`, `climate_hru`, `temp_dist2`, `precip_dist2`, `ide_dist`, `xyz_dist`, `potet_hamon`, `intcp`, `snowcomp`, srunoff_smidx, srunoff_carea, soilzone, gwflow, routing, water_balance, nhru_summary, map_results, prms_summary, subbasin, climateflow, and basin.

- Small values (>0.0 and < 1.0E-05) of precipitation are used in computations; previously these values were assumed to be below round-off tolerance and set to 0. This affects modules obs, precip_1sta, climate_hru, ide_dist, xyz_dist2, and precip_laps.
- Small values (>0.0 and < 1.0E-06) of computed potential evapotranspiration were considered to be round-off error and set to 0; now those values are used in computations. This change affects modules potet_hamon, potet_hs, potet_jh, potet_pan, potet_pm, and potet_pt.
- climateflow module: Small values (>0.0 and < 1.0E-06) of computed mixed precipitation were considered to be round-off error and the event was set to all snow or all rain depending on the precipitation form, now those values are used in computations.
- Computation of saturation vapor pressure for module potet_pm now uses an equation by Irmak and others (2012; Journal of Hydrology, v. 420-421, p. 228), to be consistent with module potet_pt. This can reduce execution time.
- Small values (>0.0 and < 1.0E-04) specified for **hru_percent_imperv** and **dprst_area** are used in computations; previously these values were assumed to be below round-off tolerance and set to zero.
- Values of canopy interception computed between 0.0 and 1.0E-05 were considered to be round-off error and set to 0.0; these values are now left in the canopy. Module affected: intcp.
- Double precision values < 1.0D-15 are treated as zero instead of < 1.0D-10.
- Module cascade: changed check for excess GWR cascade fraction so that any values > 1 set to 1 instead of only > 1.00001. This change makes the check consistent with the HRU cascade fraction check.
- Module snowcomp:
- instead of using < –1.0E-10 to check for round-off issues in some computations, < 0.0 is now used. Instead of using > 1.0E-06 to check for round-off issues in some places, > 1.0E-09 is now used.
- values of snowpack water equivalent (*pkwater_equiv*) computed between 0.0 and 1.0E-09 were considered to be round-off error and set to 0.0; these values are now used.
- Values < 0.0 are set to 0.0 with a warning message printed when control parameter **print_debug** > -1. This condition accounts for negative round-off error due to mixed precision computations and may occur under rare conditions.

NEW FUNCTIONALITY

The values of all parameters specified in the Parameter File are now checked to determine if they fall within the suggested minimum and maximum range. If values are specified outside the range, a warning message is issued. If the user wants to specify values out of the range, set control parameter **parameter_check_flag** = 0 to deactivate these checks. Previously, select parameters were checked within individual modules.

`nhru_summary`

- Added functionality to output monthly and mean monthly time series based on the value of new control parameter **nhruout_freq** (1 = daily, 2 = monthly, 3 = both, 4 = mean monthly), daily files have the suffix .csv; monthly files have the suffix `_monthly.csv`, and mean monthly have the suffix `_meanmonthly.csv`.

`gwflow` and `cascade`

- Added option to allow GWRs to be swales with new control parameter **gwr_swale_flag** (0 = not allowed; 1 = groundwater flow routed to groundwater sink; 2 = groundwater flow routed to stream network).

`cascade`

- Allow groundwater-reservoir cascades to be equal to HRU cascades with **cascadegw_flag** = 2.

`call_modules`

- Specification of control parameter **print_debug** = -1 reduces amount of screen output.

`ccsolrad`

- Removed restart subroutine so `ccsolrad` can be used in a restart simulation if `ddsolrad` was used for the antecedent simulation. The switch from `ddsolrad` to `ccsolrad` is still allowed.

`snowcomp`

- Code added to initialize snow states based on **snowpack_init** and related parameters in the “init” procedure.

`water_balance`

- Code related to GSFLOW removed.

`basin_sum`

- Labeled first value of reports as initial storage.
- Added print of water balance values to reports when **print_type** = 1
- Added print of *basin_intcp_stor* and *basin_lakeevap_yr* to yearly report when **print_type** = 2

`map_results`

- Stop if negative mapping fraction specified.
- Allow values > 0.0 and 1.0E-06 for parameter **gvr_cell_pct** instead of treating them as 0.0.

MODULES REMOVED

`check_nhru_params` code for module moved to function in file utils_prms.f90 that is called within `call_modules`.

`cloud_cover` code returned to module `ccsolrad`.

INPUT SPECIFICATION CHANGES:

`obs` and `climate_hru` Values in Data File or CBH File are not checked for being specified as not a number (NaN), thus user must ensure such values are not specified.

`climate_hru` Precipitation values specified in CBH Files less than 0.0 are flagged as an ERROR.

`precip_dist2` Values specified for parameter **psta_mon** less than or equal to 0 are flagged as an ERROR.

OUTPUT FILE REMOVED

The `prms.log` file is not generated as it is redundant with information written to the model output file. The log was present to produce a similar file as output by GSFLOW and included description and version of PRMS and modules.

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Version 4.0.1 – March 11, 2015

This release added new functionality, parameters, and variables, fixed bugs, added more checks for valid input values, general code clean up. The primary change is the addition of the flexible dimension option described below that allows flexibility for specification the spatial and temporal distribution of parameter values.

NEW MODULES (code taken mostly from existing modules)

`potet_pm` Penman-Monteith potential evapotranspiration computation and distribution module, activated using control parameter **et_module**.

`check_nhru_params` select **nhru**-dimensioned parameter values are checked to see if specified values are within the suggested range.

`prms_time` module for time related computations, such as current time step, Julian day, and whether in summer or winter.

`routing` computes variables used by stream flow modules, such as code related to fluxes associated with each segment.

`lake_route` reads most lake related dimensions, parameters, and computes some of variables used with lake computation modules.

`water_balance` debug module that checks that water balances are maintained for the overall water budget, soil-zone computations, canopy interception computations, snow computations, surface runoff and impervious computations, and groundwater computations. Active when **print_debug** is specified equal to 1.

`nhru_summary` produces output files of daily computed results for user-selected **nhru**-dimensioned variables in a CSV format. Results for each selected variable are written to a separate file.

GENERAL

- Initialize procedure is completed prior to stopping for input parameter range errors. Previously, the simulation would stop after finding the first invalid parameter value. Thus, more invalid values can be caught in a single execution. This is activated using new control parameter **parameter_check_flag**, which is described below.
- Updated many parameter and variable descriptions to be consistent with PRMS documentation manual.
- Initialize procedure is completed prior to stopping for input parameter range errors. Previously, the simulation would stop after finding the first invalid parameter value. Thus, more invalid values can be caught in a single execution. This is activated using new control parameter **parameter_check_flag**, which is described below.
- Updated many parameter and variable descriptions to be consistent with PRMS users' manual.
- Use of initial conditions options (activated using control parameters **init_vars_from_file** and **save_vars_to_file**) does not write parameter values to the Initial Condition File. Parameter values specified in the Parameter File are read and used in a restart simulation. Storage initialization parameter values, parameters **soil_moist_init**, **soil_rechr_init**, **snowpack_init**, **ssstor_init**, and **gwstor_init**, are ignored in a restart simulation. Writing to and reading from Initial Conditions Files are removed from modules `potet_hamon`, `transp_frost`, `potet_jh`, `smbal_prms`, `ssflow_prms`, `soltab`, `precip_dist2`, `hru_sum_prms`, `ccsolrad`, `ddsolrad`, `precip_1sta_laps`, `prms_summary`, `subbasin`, `basin`, `cascade`, and `map_results`. Thus, these modules do not have to be active in a restart simulation if active in a spin-up (or antecedent) simulation, except for `basin`, which is always active.

- New variable (*IGNOREPPT*=1.0E-5) added. It is used to check for values of measured or computed precipitation values that are considered too small to be actual precipitation. If a precipitation value is less than *IGNOREPPT* the value is set to 0.0.
- New variable (*SMALLPARAM*=1.0E-4) added. It is used to check a few parameter values for being too small to be used and thus set to 0 a warning message is printed if **parameter_check_flag** specified equal to `0`. Parameters checked include **pmn_mo**, **psta_mon**, and **lake_coef**. An error message is issued, and execution stops if control parameter **parameter_check_flag** is specified equal to `1` for this check.
- Code related to computations of far field flows (flow leaving the model domain boundary not through the stream network) was removed. Adding an extra stream segment to send flow outside the domain is the recommended replacement.

NEW FUNCTIONALITY ADDED TO MODULES

Flexible dimension option: Previously, parameters had only one option for the number of values (dimension(s)) specified in the Parameter File. Now, many parameters can be specified using the original dimension(s) or using compatible dimensions up to a maximum number of values based on the specified dimension(s). For example, some parameters having dimension of **nmonths** now have a maximum dimension of **nhru**,**nmonths**. Flexible dimensions for a parameter with a maximum dimension of **nhru**,**nmonths** are **one**, **nmonths**, **nsub**, **nsub**,**nmonths**, **nhru**, and **nhru**,**nmonths**. Flexible dimensions for a parameter with a maximum dimension of **nhru** are **one**, **nsub**, and **nhru**. Flexible dimensions for a parameter with a maximum dimension of **nssr** are **one**, **nsub**, and **nssr**. Flexible dimensions for a parameter with a maximum dimension of **ngw** are **one**, **nsub**, and **ngw**. PRMS will read the dimension, number of values, and values from the Parameter File. If the parameter is not specified at the maximum dimension, the parameter values will be automatically expanded to the maximum dimension by the code. Thus, the user has several options to specify the number of parameter values based on the spatial and temporal variability, available data, or for some other purpose. The maximum number of values for most parameters has not changed. Maximum parameter dimensions are identified in PRMS-IV updated tables 1-1 and 1-3 (ftp://brrftp.cr.usgs.gov/pub/mows/software/prms/4.0.1/PRMS_tableUpdates_4.0.1.pdf). The flexible dimension option was added to accommodate simulation of large model domains that required increased spatial and/or temporal distribution of parameter values. Additionally, the number of lines in Parameter Files can be significantly reduced by specifying a single (dimension **one**) or **nsub** values for parameters that have a constant value for all HRUs or subbasins. This capability may change results when dimensions are specified greater than the original dimension(s). If the parameter dimensions are not changed, results should be the same. However, some computations in `ddsolrad` and `ccsolrad` are based on variables for each HRU rather than basin-wide variables, so the potential solar radiation (variable *swrad*) can be significantly different than previous versions for large model domains.

Parameters affected with maximum dimension indicated are: **hamon_coef**(**nhru**,12) in module potet_hamon, **jh_coef**(**nhru**,12) in module potet_jh, **radadj_intcp**(**nhru**,12), **radadj_slope**(**nhru**,12), **dday_intcp**(**nhru**,12), **dday_slope**(**nhru**,12), **tmax_index**(**nhru**,12), and **radmax**(**nhru**,12) in module ddsolrad, **radadj_sppt**(**nhru**), **radaj_wppt**(**nhru**), **ppt_rad_adj**(**nhru**,12), **crad_coef**(**nhru**,12) , **crad_exp**(**nhru**,12), and **radmax**(**nhru**,12) in module ddsolrad, **epan_coef**(**nhru**,12) in modules potet_pan and intcp, **potet_sublim**(**nhru**) in modules snowcomp and intcp, **frost_temp**(**nhru**) in module frost_date), **tmax_lapse**(**nhru**,12) and **tmin_lapse**(**nhru**,12) in module temp_laps, **tmax_adj**(**nhru**,12) and **tmin_adj**(**nhru**,12) in modules temp_1sta, temp_dist2, ide_dist, xyz_dist2 and temp_laps, **tmax_allrain**(**nhru**,12) , **tmax_allsnow**(**nhru**,12), and **adjmix_rain**(**nhru**,12) in modules precip_1sta, precip_dist2, climate_hru, ide_dist, xyz_dist and precip_laps, **adjust_snow**(**nhru**,12) and **adjust_rain**(**nhru**,12) in modules ide_dist and xyz_dist **melt_look**(**nhru**), **melt_force**(**nhru**), **tstorm_mo**(**nhru**,12), **cecn_coef**(**nhru**,12) , **emis_noppt**(**nhru**,12), and **freeh2o_cap**(**nhru**,12) in module snowcomp

Parameters **adj_by_hru**, **hru_subbasin**, **rain_sub_adj**, and **snow_sub_adj** that were specified for module climate_hru were removed as the flexible dimension option makes these unnecessary. **rain_adj** and **snow_adj** can have the dimensions (**nsub**,**nmonths**), so are used instead of **rain_sub_adj**, and **snow_sub_adj**. Parameter **hru_subbasin** is required if module subbasin is active.

An example of parameter with a maximum number of values equal to **nhru** that might have the same value for all HRUs is **carea_max**. In this case, values for each HRU can be specified to the default value as:

```
####
carea_max
1
one
2
0.6
```

map_results added option to output daily mapped results (parameter **mapvars_freq** specified equal to 7). Notes: the units of output variables are equal to the units of the variable for **mapvars_units** specified equal to 0. Units for variables could be, for example, inches, inches/day, degrees Fahrenheit, and degrees Celsius. However, when the **mapvars_units'** value is specified greater than 0, the units of all selected **map_results** output variables as specified by control parameter **mapOutVar_names** must have units of either inches or inches/day as the code only converts inches to a metric unit.

climate_hru CBH files can be input as binary files with the identical information when new control parameter **cbh_binary_flag** specified equal to 1. Humidity and wind speed data can be input as CBH files. Potential ET can be adjusted from values input in CBH files using new parameter **potet_cbh_adj**.

strmflow_lake the order of stream segments and lakes was specified by parameters input to the cascade module with **wtrbdy** prefix-named parameters. The module now uses the same parameters as other stream network routing modules, that is, **tosegment**, **hru_segment**, and **obsin_segment**. This change requires that each lake includes a stream segment as well as being specified as a lake HRU. A segment within a lake is specified using **segment_type**.

obs and call_modules store dimension values in Initial Conditions Files for a spin-up simulation and are checked to be sure they are the equal to the dimensions for a restart simulation.

prms_summary added output of the first value of the variable *streamflow_cfs* array to the CSV file (control parameter **csvON_OFF** specified equal to 1); if the value of dimension **nobs** is specified equal to 0, then the value 0.0 is output for *streamflow_cfs*.

NEW PARAMETERS

Parameters specified in the Control File

parameter_check_flag 0 means treat some parameter range checks as WARNINGs as done for most parameters in previous versions, if specified as 1 these checks are treated as ERRORs, if specified as 2 the parameters are checked and then the simulation stops even if no ERRORs, default = 1.

cbh_check_flag 0 means do not check values in CBH file; 1means to check for invalid values, such as NaN, character strings, < lower bound, and > upper bound, plus end of file during a simulation and non-sequential time series, such as not having the correct number of days in each year, default = 1. Specifying **cbh_check_flag** equal to 0 should only be done after the CBH file(s) are verified using **cbh_check_flag** specified equal to 1. Setting **cbh_check_flag** equal to 0 can reduce execution time.

cbh_binary_flag 0 means CBH files are text files as in the past; 1 means the CBH files are in binary format with same order of values as text file version.

nhruOutVar_names array of variable names to write to CSV files each day.

nhruOutBaseFileName string to define the prefix for each output file for the nhru_summary module, one for each variable; this can be a full or relative path.

nhruOutON_OFF flag to activate nhru_summary module (0 means do not use module; 1 activates module, default = 0).

nhruOutVars number of output variables, i.e., the number of variable names specified using **nhruOutVars_names**.

csv_output_file pathname of output file written by the prms_summary module.

csvON_OFF flag to activate the `prms_summary` module (0 means do not use module; 1 activate module, default = 0).

humidity_cbh_flag flag to specify to read a CBH file with humidity values (0 = no; 1 =yes, default = 0).

humidity_day file name of the humidity CBH file; this can be a full or relative path.

windspeed_cbh_flag flag to specify to read a CBH file with wind speed values (0 = no; 1 = yes, default = 0).

windspeed_day file name of the wind speed CBH file; this can be a full or relative path.

print_debug: new option (**print_debug** specified equal to -1) added to this existing parameter that minimizes warning messages and other messages printed to the screen during a simulation, such as when values of variables *slow_stor* are computed greater than *pref_flow_thrsh*. This can increase execution efficiency.

Parameters specified in the Parameter File(s)

dprst_et_coef(**nhru**): surface-depression evaporation adjustment factor, range 0.0 to 1.0, default = 1.0.

sro_to_dprst_imperv(**nhru**): impervious surface runoff fraction captured by surface depressions within each HRU. Related parameter **sro_to_dprst**(**nhru**) is pervious surface runoff capture fraction captured by surface depressions within each HRU, range 0.0 to 1.0, default = 0.2.

segment_flow_init(**nsegment**): initial flow rate in each segment, in cfs, range 0.0 to 1.0E07, default = 0.0.

segment_type(**nsegment**): Segment type 0 = segment; 1 = diversion; 2 = lake; 3 = replace inflow, default = 0.

hs_krs(**nhru**,**nmonths**): calibration coefficient for module `potet_hs`; replaces removed parameter **potet_coef_hru_mo**(**nhru**,**nmonths**), range 0.005 to 0.06, default = 0.0135.

pt_alpha(**nhru**,**nmonths**): calibration coefficient for module `potet_pt`; replaces removed parameter **potet_coef_hru_mo**(**nhru**,**nmonths**), range 1.0 to 2.0, default = 1.26.

potet_cbh_adj(**nhru**,**nmonths**): calibration coefficient for values specified in a **potet_day** CBH file, range 0.5 to 1.5, default = 1.0.

snowpack_init(**nhru**): initial snowpack-water equivalent, in inches, range 0.0 to 500.0, default = 0.0.

NEW COMPUTED VARIABLES (available depending on which computation options are active):

canopy_covden(**nhru**): current value of cover density fraction for each HRU based on whether HRU is in transpiration mode.

hru_intcpevap(**nhru**): canopy evaporation for each HRU, in inches.

hru_storage(**nhru**): sum of all storage for all water-holding reservoir for each HRU, in inches.

lake_seepage_gwr(**nhru**): the seepage from lakes to each GWR in units of inches.

gw_seep_lakein(**nhru**): dimensioned changed from **nhru** to **nlake**, in inches.

dprst_stor_hru(**nhru**): average surface depression storage for each HRU, in inches.

basin_contrib_fraction: basin-area weighted average contributing area fraction of pervious area.

contrib_fraction(**nhru**): contributing area fraction of the pervious area of each HRU.

basin_lake_stor: basin-area weighted average precipitation into all lakes, in inches.

basin_lakeevap: basin-area weighted average evaporation from all lakes, in inches.

unused_potet(**nhru**): unsatisfied potential evapotranspiration after all ET computations, in inches.

basin_segment_storage: basin-area weighted average total storage in each segment, in inches.

segment_delta_flow(**nsegment**): cumulative difference of flow into minus outflow for each stream segment, in cfs.

seginc_potet(**nsegment**): potential ET associated with each segment, in inches.

lake_inflow(**nlake**): total inflow into each lake, in cfs.

lake_outflow(**nlake**): total evaporation and seepage from each lake, in cfs.

lake_lateral_inflow(**nlake**): total lateral flow into each lake, in cfs.

hru_streamflow_out(**nhru**): total flow to stream network for each HRU, in cfs.

hru_hortn_cascflow(**nhru**): name change for variable *hru_hortonian_cascadeflow*, in inches.

snowdepth(**nsnow**): name change of variable *snow*, in inches.

lake_outcfs(**nsegment**): name change of variable *lake_outq*, in cfs.

BUG FIXES

`snowcomp`: Computation of snowpack density and snowpack depth are computed based on a finite difference approximation, which produced slightly incorrect results for days when new snow falls when a snowpack does not exist. This bug could produce significant error when the new snow fall is large compared to the existing snowpack. There was the possibility that the snowpack water equivalent was computed as a value < 0 when the amount of free water was less than the computed amount of free water that the snowpack could hold. Though this condition is likely very rare, it could have resulted in very slight differences in results in the value of variables *pkwater_equiv*, *pk_depth*, and *snowmelt*.

ide_dist and xyz_dist: measured precipitation values were modified from those in the Data File, thus output values in runtime graphs or files could be different than those in the Data File; a local array is used instead.

basin_sum: water balance computations did not include water in stream segments when using Muskingum flow routing or surface depression storage, if any. Water balance computations are only computed when control parameter **print_debug** = 1. Used variable *basin_stflow_in* instead of *basin_stflow_out* to set the basin outflow variable *basin_cfs*, this bug only occurred when the muskingum module was active.

basin: The contributing area to each stream segment was computed incorrectly for some cases. Error check added for specification of any **tosegment** value equal to that segment, if this were done the code would go into an infinite loop. Checks added for valid values of **tosegment**; error if > **nsegment**, < 0, or equal to the segment id. Setting of local variable *hru_elev_feet* was not set when parameter **elev_units** was specified as 1; this only affected computations when module potet_pt is active. Print of fraction of impervious, pervious, and depression storage were labeled as area instead of as fractions of the active basin area.

gwflow: Values of parameter **gwflow_coef** specified less than 1.0 are allowed and if specified > 1.0 a warning is issued. Any water added due to specified values of parameter **gwstor_min** was added twice. Error message for the condition that an HRU is specified as a lake and the associated value of parameter **lake_hru_id** is specified equal to 0, printed the incorrect GWR Identification number. If groundwater discharge to a lake was computed greater than the available groundwater storage, the value was not limited by the available storage; now the discharge is set to the available groundwater storage and a warning message is issued. Computation of lake seepage was removed from the initialize procedure, so the initial lake elevation and storage is based only on input parameters instead of after lake elevation and groundwater discharge computations as computed in the run procedure. Warning checks of parameters used incorrect array index. If any HRUs were specified as inactive then the last number of inactive HRUs values were not checked. Seepage from lakes used the incorrect array index, thus, was set incorrectly. *basin_lake_seep* was divided by the total active area of the model domain twice; thus the value was incorrect.

soilzone: Error check added for interflow computation of the equation SQRT(**coef_lin****2.0+4.0***coef_sq****ssres_in*) = 0.0, if true a divide by 0 would have occurred, this would be a very rare condition. Corrected setting of variable *soil_zone_max* to account for parameter **soil_moist_max** only being applicable to the pervious area of each HRU, this does not affect other soilzone computations, just the values of variables *soil_zone_max* and *soil_moist_frac*, which are computed results that are not used in other computations. Water balance check when control parameter **print_debug** = 1 was incorrect when swale HRUs are present.

ccsolrad, ddsolrad, ccsolrad_prms, and ddsolrad_prms: assumed it was always winter for Southern Hemisphere applications.

`write_climate_hru`: if a transpiration CBH file was specified and the value for control parameter **transp_module** was specified as **climate_hru_mo**, the CBH file was not correctly produced.

`frost_date`: write of parameter names was incomplete as the output string was not allotted enough characters. Fix was made in functions `write_integer_param` and `write_real_param` that are found in the file `utils_prms.f90`. If a spring or fall frost was not found in a year a divide by zero error was possible. The values for output parameters **spring_frost** and **fall_frost** were output as solar days instead of calendar day, i.e., 10 days are now added to the computed solar day. Function `julian_day`, found in the file `utils_prms.f90`, incorrectly computed solar day.

`transp_frost`: Function `julian_day`, found in the file `utils_prms.f90`, incorrectly computed solar day.

`lake_route` and `strmflow_lake`: if an HRU is a lake, the value for the local variable *gwr_type* for that HRU was incorrectly set to 2; it is now set to 1.

`srunoff_smidx` and `srunoff_carea`: The amount of water used to compute Hortonian runoff from cascading surface runoff was computed as a value on pervious areas only instead of the amount of water from the entire contributing HRUs; thus, could produce significant error when impervious fraction of HRUs is large. The values of variables *hru_sroffi* and *basin_sroffi* were not set correctly when parameter **imperv_stor_max** was specified equal to 0.0 for impervious portions of HRUs.

CHANGES THAT MIGHT PRODUCE SLIGHT CHANGES IN ASSOCIATED COMPUTATIONS – general:

- Most double precision variables changed to single precision to provide more consistent floating-point comparisons and have more consistent round-off issues. Change reduces memory requirements up to 10% and slight decrease in execution time.
- Changed variables *seginc_ssflow*, *seginc_sroff*, *seginc_gwflow*, *seginc_swrad*, *seg_outflow*, *seg_inflow*, *lake_area*, *dprst_sroff_hru*, *dprst_seep_hru*, and *hortonian_lakes* changed from single to double precision as they are sums for sets of HRUs. Only *seg_outflow* and *seg_inflow* are used in computations in multiple modules, while; the others only are computed for output purposes.
- Changed check for very small values from 5.0E-6 to 1.0E-6 to better represent round-off error.

CHANGES THAT MIGHT PRODUCE SLIGHT CHANGES IN ASSOCIATED COMPUTATIONS – by module:

`cascade`: tolerance used to check for the fraction leaving an HRU or GWR adding up to exactly 1.0 changed from 1.00001 to 1.001. If this check finds an issue the cascade links are adjusted.

potet_pan, potet_jh, potet_hamon, potet_hs, potet_pt, and potet_pm: now sets potential evapotranspiration to 0.0 for values computed less than 1.0E-6 instead of only when a computed value was negative. Thus, very small computed potential evapotranspiration values are ignored.

potet_pt: constant used to compute saturation vapor pressure changed from 17.269 to 17.26939. Equation to compute the latent heat of vaporization were computed in units of Calories/gram and then converted to kilojoules/kilogram. Now they are computed in units of kilojoules/kilogram.

ccsolrad: now sets computed canopy density to 0.0 for values < 1.0E-6 instead of only if computed value was negative. Thus, very small, computed canopy density values are ignored.

intcp: values of parameters **covden_win** or **covden_sum** specified < 1.0E-4 and some computations that result in values very < 1.0E-5 are not reset to 0.0 as previously done.

snowcomp: set some and compares other computations to being less than 1.0E-6 instead of less than 0.0, which can allow for very small values of some variables. Canopy density on each HRU for each time step is used in computations instead of only values of parameter **covden_win**. If parameters **den_init** and/or **den_max** values are specified less than 1.0E-06, they are set to 1.0E-06 instead of 0.1 and 0.6, respectively.

srunoff: value of variable *hru_hortn_cascflow* was not reset to 0.0 for each time step; computed value is not used in other computations and is only available when cascading flow is active. Removed check for computed values of *imperv_stor* less than 0.0 and then reset to 0.0 to allow for round-off error bias to be reduced.

gwflow: computation of surface-depression storage fractions for round-off issues would sometimes produce very small, closed depression storage fractions, which is now fixed.

soilzone: Added checks for computed infiltration less than 0.0 and computed interflow coefficient equal to 0.0, these would not likely occur.

ddsolrad: if computed radiation adjustment factor based on parameters **dday_slope** and **dday_intcp** is greater than the value of parameter **radmax**, it is set to **radmax** rather than as computed.

frost_date: the sum of local variables *fallFrostSum* and *springFrostSum* computed as floating-point values instead of integer prior to rounding to nearest integer. These values were set to the truncated integer values, they are now rounded, that is, set to the nearest integer. Maximum value of the fall frost changed from 366 to 365 and minimum value of spring frost changed from 0 to 1. Computation of the *basin_fall* and *basin_spring* uses rounding of the integer value instead of truncation.

transp_tindex: all computations use degrees Fahrenheit instead of checking temp_units and converting computations to Fahrenheit, this should not produce a noticeable change in results, but does increase execution efficiency. When the value of parameter **transp_end** equals the current month and the current day is the first day of the month transpiration is turned off (variable *transp_on* is set to 0) and the related local variables, *transp_check* and *tmax_sum*, are set to 0. After this check, if the current month equals the value of parameter **transp_beg**, *transp_check* and *tmax_sum* are checked to determine if transpiration needs to be turned on if the value of *tmax_sum* is greater than the value of parameter **transp_tmax**. If true variable *transp_on* is set to 1, *transp_check* is set to 1 and, tmax_sum is set to 0. Previously, the checks were reversed, which could keep transpiration on for a few days in a month, depending on the value of *tmax_sum* when the value of **transp_beg** and **transp_end** were specified equal to each other.

`muskingum`: allow specification of parameter **K_coef** to be less than 1.0, if found a warning message is issued instead of an error message when control parameter **parameter_check_flag** is specified greater than 0. If computed Muskingum flow coefficient (*c2*), based on parameters **K_coef** and **x_coef**, for a segment is < 0.0, this means the travel time through segment is small, thus outflow is primarily equal to inflow for the segment. If this condition is true, the computed Muskingum coefficient *c1* is decreased by the computed value of coefficient *c2* and *c2* is set to 0.0. If the computed value of Muskingum coefficient *c0* is < 0.0 then outflow from a segment would be greater than a day, the maximum travel time, which is mainly dependent on yesterday's flows. If this condition is true, the value of *c1* is decreased by *c0* and *c0* is set to 0.0. Previously, those Muskingum equation coefficients were not adjusted based on these conditions.

`temp_1sta` and `temp_laps`: initial value used to replace a missing value changed from 50.0 **tmax_allrain**(*start_month*), this only affects the first time step.

`basin`: reordered code to determine variables *hru_perv*, *hru_imperv*, *dprst_frac_hru*, *dprst_area_max*, *dprst_frac_open*, *dprst_frac_clos*, *dprst_area_clos_max*, *dprst_area_open_max* to maintain restriction that the fraction of the HRU that is pervious is at least 0.0001. This change might produce slight changes in results for rare combinations of input parameters.

`map_results`: **gvr_cell_pct** values specified less than 1.0E-6 are set to 0.0, previously the lower limit was 1.0E-10.

`obs`: measured precipitation values specified less than 0.0001 are set to 0.0.

INPUT SPECIFICATION CHANGES – by module:

`ccsolrad` and `ddsolrad`: check added to be sure at least one value of parameter **hru_solsta** is specified greater than 0 when dimension **nsol** is specified greater than 0. If all values of **hru_solsta** were specified equal to 0 an array would be referenced beyond its memory limit.

`basin_sum`: the default value for parameter **print_freq** changed from 1 to 3.

`basin`: error check added to be sure dimensions **nhru** = **nssr** = **ngw** when using the surface-depression storage computation option. Error check added for values of parameter **op_flow_thres** specified greater than 1.0. Added check for values of parameter **hru_percent_imperv** specified less than 0.0 or greater than 0.999. Previously, if either of these conditions were true, the values were set to 0.0 and 0.999, respectively; now an error message is printed, and execution stops. Added check for HRUs not connected to a stream segment as specified using parameter **hru_segment**. This check is applicable only when stream-segment routing and/or cascading flow routing are inactive; a warning message is issued to the screen and written in the Model Output File identifying any HRUs not connected. Added check for values of parameter **dprst_area** specified greater than the corresponding value of **hru_area** for any HRU; an error message is printed, and execution stops. Added check for isolated stream segments, that is a segment that does not receive inflow or flow to another segment as specified by parameter **tosegment**); error unless control parameter **parameter_check_flag** is specified equal to 0. Added checks to be sure valid values of **elev_units** and **cov_type** are specified; if an invalid value an error message is printed, and execution stops. Values of parameters **soil_moist_max** and **soil_rechr_max** are set to 0.0001 if less than 0.0001 instead of set to 0.001 if less than 0.001. Values of parameters **hru_percent_imperv**, **dprst_area**, **op_flow_thres** and computed values of **dprst_area**/**hru_area** are set to 0.0 if less than 0.0001 with warning message issued.

`gwflow`: checks added for values of parameter **gwflow_coef** specified greater than 1.0 or GWRs specified as being a swale; if these conditions are found a warning message issued.

`srunoff_smidx` and `srunoff_carea`: added check for values of parameter **carea_max** specified greater than 1.0; if true an error message is printed, and execution stops. Added check for the computation of local variable *carea_max* for `srunoff_smidx` based on parameters **smidx_coef**, **smidx_exp**, and **soil_moist_max** results in a value greater than 2.0; warning message is printed if control parameter **parameter_check_flag** specified equal to 1. Added checks for values of parameters **dprst_flow_coef**, **dprst_seep_rate_open** and **dprst_seep_rate_clos** specified greater than 1.0; if true an error message is printed, and execution stops.

`soilzone`: don’t reset parameters **ssr2gw_rate**, **soil_moist_init**, **soil_rechr_init**, **ssstor_init**, **sat_threshold**, **slowcoef_lin**, **slowcoef_sq**, **fastcoef_lin**, and **fastcoef_sq** if they are specified as invalid, instead if true an error message is printed, and execution stops. Specification of **soil_rechr_max**>**soil_moist_max**, **soil_moist_init**>**soil_moist_max**, **soil_rechr_init**>**soil_moist_max**, *ssres_stor*>**sat_threshold**, **soil_rechr_init**>**soil_rechr_max**, **soil_moist_max**<0.0001, and **soil_rechr_max**<0.0001 are treated as warnings and reset to valid values instead of errors when control parameter **parameter_check_flag** specified equal to 0, previously these always were treated as errors. Added checks for **slowcoef_sq**, **slowcoef_lin**, **fastcoef_sq**, and **fastcoef_lin** specified equal to 0 as this could cause a divide by zero; if true an error message is printed and execution stops unless **parameter_check_flag** is specified equal to 0, for which a warning message is printed and any values less than 0.0001 are set to

0.0001. Check added for specifying valid values of **soil_type**, which can be 1, 2, or 3; if any invalid values are specified an error message is printed and execution stops.

`climateflow`: make sure parameters **basin_solsta** and **basin_tsta** are always assigned a valid value, which is needed as they are written to the restart file. Added check for computed values of *tmaxf* greater than *tminf*; if true a warning message is printed, and execution continues.

`potet_pan`: added check to be sure pan evaporation time series is included in Data File, if values of parameter **hru_pansta** are specified greater than dimension **nevap** or equal to 0 an error message is printed, and execution stops.

`intcp`: if a values of parameter **epan_coef** are specified less than 0 an error message is printed, and execution stops. This check is made only when pan evaporation data are included in the Data File. If any values of parameters **covden_win** or **covden_sum** is specified less than 0 or greater than 1 an error message is printed, and execution stops.

`xyz_dist` and `ide_dist`: added checks to be sure data for at least 2 temperature and precipitation measurement stations are specified to be used in computations.

`xyz_dist`: added check for specifying values of parameters **x_div**, **z_div**, **y_div**, **ppt_div**, **tmax_div**, and **tmin_div** equal to 0.0, as 0.0 would cause a divide by 0.0. If true an error message is printed, and execution stops.

`potet_jh`: added check for values of parameter **jh_coef_hru** specified greater than 150 or less than -50 and values of **jh_coef** specified greater than 10 or less than -1; if true a warning message is printed when control parameter **parameter_check_flag** is specified equal to 0; else an error message is printed and execution stops.

`map_results`: added check to be sure the type of selected output variables is either real or double. Added check for selected output variables dimensioned by a value not equal to dimension **nhru**. Added checks for specification of **gvr_cell_id** values greater than dimension **ngwcell** and **gvr_hru_id** values specified greater than dimension **nhru**. If any of these checks are true an error message is printed, and execution stops. If the value of parameter **mapvars_freq** is specified equal to 0 then the `map_results` module is not active even if control parameter **mapOutON_OFF** is specified equal to 1. If dimensions **nhru** and **nhrucell** are specified with equal values, then parameters **gvr_hru_id** and **gvr_cell_pct** are not required and ignored if specified in the Parameter File(s).

`temp_1sta` and `temp_laps`: if too many missing values (greater than parameter **max_missing**) were found an error message is printed and the execution stops instead of continuing.

`call_modules`: added checks for deprecated module names, if found a warning message is printed, but allow to maintain downward compatibility for older applications the module name is set to the current name.

OUTPUT CHANGES

- Print of list of valid modules with longer and more consistent descriptions.
- When climate_hru is active for more than one type of CBH file, the module description is printed for each climate type. For example, if climate_hru is used to input temperature and precipitation values, a line is printed with the climate_hru version identification for the active Temperature Distribution and Precipitation Distribution modules. Previously, the identification was printed once no matter how many climate types input were using climate_hru.
- HRU identification numbers are printed allowing for seven digits instead of six throughout the code.
- File: temp_1sta_laps.f90 added print of module version identification as it was missing.
- File srunoff.f90 print of module version identification changed to indicate whether using srunoff_smidx or srunoff_carea method.
- basin_sum: when control parameter **print_debug** value is specified equal to 4, some debug values were summed instead of printed individually. Write variable *basin_potsw* instead of *orad* in summary tables. Printing of water balance values changed from F9.4 to F9.3.
- New function print_date added in file utils_prms.f90, which is used to print the current time step in consistent formats for warning and error messages: modules affected: potet_pan, ddsolrad, precip_dist2, ccsolrad, temp_dist2, obs, ide_dist, snowcomp, gwflow, climateflow, and soilzone.
- New functions check_param_value, check_param_limits, checkint_param_limits, checkdim_param_limits, check_param_zero, and check_restart_dimen added in file utils_prms.f90 so that duplicate code is reduced for checking many parameters for valid input values and to make warning and error messages more consistent.
- soilzone: message for values of variables *slow_stor* > *pref_flow_thrsh* can be turned off as well as many warning messages for other modules if control parameter **print_debug** is specified equal to -1; this message was printing for very small differences.
- call_modules: allow the same file name to be used control parameters **save_vars_to_file** and **init_vars_from_file**, need to be careful as this means the values stored when the file was first generated are overwritten. The start and end clock date and time and the elapsed time at end of simulation are output to the screen in the Model Output file.
- prms_summary: changed output format of variable values from F12.6 to PE14.6.

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Version 3.0.5 – April 24, 2012

This release mainly focused on general code clean up and bug fixes.

General

MMF declmodule replaced with Fortran print_module.

MMF write and open of **model_output_file** replaced with Fortran routines (opstr replaced with write_outfile). Affected modules: hru_sum_prms, basin_sum, basin, and call_modules.

MMF functions isleap and julian replaced with Fortran functions leap_day and julian_day.

MMF function getstep replaced with an internal counter the current time stop (variable *Timestep*) is set to 0 in basin and incremented in obs.

Parameter checks in initialize procedure only performed for active HRUs.

Restart capability added to all except: potet_hs, potet_pt, potet_hamon_prms, temp_2sta_prms, ccsolrad_prms, ddsolrad_prms, hru_sum_prms, frost_date, write_climate_hru.

Files precip_1sta.f90 and precip_laps.f90 combined into single file: precip_1sta_laps.f90.

Files temp_1sta.f90 and temp_laps.f90 combined into single module: temp_1sta_laps.f90.

Files srunoff_smidx.f and srunoff_carea.f combined into single file: srunoff.f90.

transp_frost: parameters **spring_frost** and **fall_frost** only checked for active HRUs to set initial values of *basin_transp_on* and *transp_on*.

write_climate_hru: changed output format from E10.2 to E12.4.

ddsolrad: determination if the simulation time is in the summer based on equinox for the Northern and Southern Hemisphere is determined in the obs module instead of this module so that this code is in on location.

Files temp_dist2.f, precip_dist2.f, strmflow_lake.f, soilzone.f, climateflow.f, call_modules.f converted to F90: temp_dist2.f90, precip_dist2.f90, strmflow_lake.f90, soilzone.f90, climateflow.f90, and call_modules.f90.

obs: make sure **runoff_units** has a value when **nobs** = 0; set *summer_flag*, increment *Timestep*.

utils.f90: added check to be sure when reading *orad* that the variable name is *swrad*, which is the variable name used by write_climate_hru. This could be a problem for people who generated their own swrad CBH file and used a different variable name.

basin: changed NEARZERO from 1.0E-7 to 5.0E-6; DNEARZERO from 1.0D-12 to 1.0D-10 to better represent round-off error. Removed parameter **basin_area**. Segment routing order computation moved to here and removed from streamflow routing modules to reduce duplicate code.

cascade: code related to water-body cascades removed. Instead, the **tosegment** is used and a stream segment must be associated with each lake if present.

New module: strmflow_in_out, which routes flow through the stream network without assuming a routing travel time; thus, outflow from a stream segment equals the sum of the inform from any upstream segments and any lateral flows from associated HRUs.

File potet_jh.f90: merge of files potet_jh.f90 and potet_jh_hru.f90.

File srunoff.f90: merge of files srunoff_smidx.f and srunoff_carea.f. New parameter **dprst_et_coef**(**nhru**) was added to adjust evaporation potential from surface depressions. Evaporation from open depressions is computed prior to evaporation from closed. Both are computed at the potential rate, limited by unsatisfied ET. Unsatisfied ET is reduced after computing open evaporation to then limit closed evaporation. This was being done in a complicated way, which is now streamlined.

strmflow_lake: routing strategy using cascade water body code replaced with **tosegment** order, which requires a stream segment to be associated with each lake. Code to computes fluxes by segment, such as *seginc_gwflow*, *seginc_ssflow*, *seginc_sroff*, *seginc_swrad*, *seg_lateral_inflow*, and *hru_outflow*. Module was reorganized and has had little testing.

BUG FIXES

potet_pan: check dimension **nevap** > 0 in declare procedure instead of initializing to avoid memory error. CRITICAL BUG FIX: module would not run as return code set to 1 instead of 0. If **nevap** < 1, simulation stops with error message. Valid values for **hru_pansta** checked for active HRUs only.

transp_index: changed maximum value from 12 to 13 so module works with paramtool fix option. Set *transp_end_12* for each HRU so that there is a value so as to write the variable to the restart file.

basin_sum: **print_freq** = 6 did not produce monthly and yearly tables, now does. Variables *basin_runoff_ratio* and *basin_runoff_ratio_mo* were in units of inches/cfs, changed to inches/inches (decimal fraction).

snowcomp: allow **cov_type** to be > 2 to designate trees, was limited to **cov_type** = 3 gwflow: minimum **elevlake_init** changed from 0.0 to -10000.0 feet. BUG FIX: with strmflow_lake active with weirs or gates, *seepage_gwr* was in inches when it needed to be in acre-inches.

muskingum: default for variable *TS* was set to 0.0 instead of 1.0, which for **K_coef** values < 1.0 would cause *x_max* to be set to 0.0 (not sure if this was a bug, Michael identified this as a problem). Checks were added for **K_coef** > 24.0. If **parameter_check_fla**g = 1, this is an error, else a warning message is issued and **K_coef** is set to 24. Check added for *C2*<NEARZERO, if so, *C1* set to *C1* + *C2* and *C2* set to 0.0 (short travel time). Check added for *C0*<NEARZERO, if so, *C1* set to *C1* + *C0* and *C0* set to 0.0 (long travel time). BUG FIX: the routing loop was modified to properly include *streamflow_cfs*(**obsin_segment**(*iorder*)) in the current inflow of a segment and to set the *seg_upstream_inflow* to 0.0 for each internal time step. This module needs more verification. BUG FIX: **obsin_segment** was not working when **K_coef** was not equal to 1.0, the value was divided by the timestep instead of using the input value.

soilzone: all preferential flow computations only performed when **pref_flow_den** > 0.0 for an HRU, previously some were always computed when at least one HRU had a preferential flow reservoir. BUG FIX: the Dunnian flow from the gravity reservoir was not set correctly if a preferential flow reservoir was not present, this was only an issue when computing the soil zone water balance when print_debug = 1. This did not affect the results of the soil zone computations.

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Version 3.0.4 – January 15, 2012

This release mainly focused on bug fixes and changes to warning and error messages.

BUG FIXES

- muskingum: Value of NaN was produced for streamflow if value of **K_coef** < 1.
- musroute: *seginc_swrad* for first segment when no HRU contributes to that segment is set to second segment instead of leaving it set to 0.0.
- climate_hru: CBH files are checked to be sure first time step is valid and if end-of-file or missing day found during a simulation.
- srunoff_carea and srunoff_smidx: amount of pervious and impervious surface runoff from open and closed depressions computed incorrectly resulting in too small of surface depression storage surface runoff.
- basin_sum: water balance and *basin_stflow_tot* computed and outflow from basin printed using *basin_stflow_in* instead of *basin_stflow_out*; added variable *basin_runoff_ratio* = *basin_ppt*/*basin_cfs*.
- Input error checking changed to get through reading Parameter File (mostly) before stopping on error condition instead of stopping at first input error.

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Version 3.0.3 – November 29, 2012

This version was prepared but never released because it failed the test cases.

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Version 3.0.2 – September 22, 2012

This release mainly focused on bug fixes with a few minor changes to some input/output files, and parameters.

BUG FIXES

`soilzone`:

- limit flows produced in each reservoir to maximum capacities instead of antecedent storage + all inflow to a reservoir; this fix may result in substantial changes in results and is consistent with the PRMS conceptualization of the soil zone.
- set available potet for the average depth over the pervious portion instead of the whole HRU, this bug may have generated increased ET used by the capillary reservoir when impervious surfaces and surface depression storage are present in an HRU.
- *basin_recharge* was computed incorrectly; it was only set to the recharge value of the last HRU. D)if using `strmflow_lake` and the parameter **lake_hru_id** was not specified an invalid memory access could take place which would cause evaporation from lakes to be computed incorrectly.

`strmflow_lake`: flow out of lakes based on gate openings were computed using values specific to a single lake model, this was changed to be applicable to any model.

`cascade`: when greater than 2 cascades from a source to a destination, one or more of these cascades could have been ignored and fraction of cascade computed incorrectly. This would be a rare occurrence and was true for HRU and GWR cascade specifications.

`intcp`: A) if pan evaporation data are in Data File (**nevap**>0) and the ET module is not `potet_pan` then they are ignored rather than used as *potet*; B) allow winter cover density to be greater than summer density; previously if winter density was specified > summer, winter density was set to summer.

`map_results`: the number of output rows were computed incorrectly, if the dimension **ngwcell** was not equal to **ngwcell**/**ncol** and if nhru does not equal **nhru**/**ncol**.

`obs`: negative input values of observed runoff were set to -11; they are not changed from the values specified in the Data File; this could have caused problems with automated calibration programs.

OUTPUT AND INPUT ISSUES

- Some variables changed from single precision to double precision, this might cause a very slight change in results that may have been due to round-off error - in modules: `precip_dist2`, `temp_dist2`, `xyz_dist`, `strmflow_lake`, `basin_sum`, and `map_results`.
- A list of available and active modules is output to the user's screen.
- Module `climate_hru` – new functionality: can input whether an HRU is in a transpiration day in a CBH file (0=no or 1=yes), previously the transpiration period was fixed for the entire simulation time period.

PARAMETER NAME CHANGES

- temperature adjustment parameters were changed from **tmax_adj** and **tmin_adj** to **tmax_cbh_adj** and tmin_cbh_adj to avoid possible duplicate use of the parameter values. Similarly, precipitation adjustment parameters were changed from **rain_adj** and **snow_adj** to **rain_cbh_adj** and **snow_cbh_adj**. Check the messages about unused **tmax_adj**, **tmin_adj**, **rain_adj**, and/or **snow_adj** parameters and **tmax_cbh_adj**, **tmin_cbh_adj**, **rain_cbh_adj** and/or **snow_cbh_adj** are required but not specified. The value of *solrad_tmax* and *solrad_tmin* is now always set to *basin_tmax* and *basin_tmin* instead of using tmax(**basin_tsta**) and tmin(**basin_tsta**) when **ntemp**>0; this can produce differences in results.
- Data File: A) missing temperature value indicator changed from less than -89 to less than -99 for modules: `temp_laps`, `temp_1sta`, `temp_dist2`, and `xyz_dist`.
- Data File: B) added in variables *humidity* and *wind_speed* and dimensions **nwind** and **nhumid**.
- Data File and Climate-by-HRU (CBH) files: Values are checked to see if any are specified as NaN (not a number), which results in an error message and stop of the execution. If any values in a CBH files are missing, the number of missing values and data type are output to the user's screen and the execution stops.
- Module `strmflow_lake`: Parameter and variable names using "sfres" or "res" as part of their name, changed to use "lake" instead. The dimension **nsfres** changed to nlake. If the dimension **nsfres** is specified, a list of all parameter names that need to change is output to the user's screen and execution halts.
- Module `temp_dist2` - if no valid temperature values found, include in a warning message to indicate that the last valid temperature values is used for that time step.
- Module `hru_sum_prms` has been deprecated and is only active if one or more of the following deprecated modules are active: `potet_hamon_prms`, `ddsolrad_prms`, `ccsolrad_prms`, and `soltab_prms`. If module `hru_sum_prms` is not active, parameters **pmo** and **moyrsum** are not needed.

- Variable *basin_stflow* is replaced with *basin_stflow_in*, the total amount of lateral flow into the stream network. Variable *basin_stflow_out* was added, which is the total amount streamflow out of the model domain.
- Module `map_results` –Added check to be sure the mapping specification is complete (**gvr_cell_id**(i)>0, **gvr_hru_id**(i)>0, and **gvr_cell_pct**>1.0E-10) from the HRU map to the target map; a warning message is output to the user's screen if this condition is detected. This check produces a warning message, as in some cases it might be desirable to map only a portion of an HRU to a target map spatial unit, such as, at a model boundary where the HRU map and target map have different spatial extents.
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Version 3.0.1 – February 06, 2012

This release mainly focused on improving the messages that come to the command line window. Many users of PRMS were ignoring the error and warning messages because that they could not be understood. Also, users were uncertain about which modules were active in the runs they were making. The new messages will help with both of these cases.

- There were some changes made to increase the precision of the snow and soil moisture module algorithms. Some of the FORTRAN variables were changed from single precision to double precision floating points. The consequence of this is some changes in the results in the simulation of snowpack storage and melt, and soil-moisture storage and recharge. These changes are evident in (sometimes) the 4th and (usually) the 5th significant digit.
- No changes were made in this version which impact the format or content of the input and output files in any way.
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Version 3.0.0 – November 15, 2011

This version of PRMS has been designed as a stand-alone program that can be executed on a Linux or Microsoft Windows platform. In some ways, this version may appear to return to the concepts and design of the earliest versions of PRMS. Much of the support functionality provided by MMS has been stripped away in favor of a "batch execution" mode for maximum application flexibility and computational efficiency. This approach also supports maximum portability between computers running the Windows and Linux operating systems. Focus has been placed on ease of deployment, installation, and reliability over the MMS concepts of "model building." However, the module and function library developed for the MMS version of PRMS have been shown to be useful and have been retained.

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MMS Version MMS-windows – January 26, 2007

The MMS version of PRMS was ported to PCs running the Windows operating system using Cygwin.

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MMS Version 1.0.0 through 1.2.1 (1991 through 2002)

These were UNIX only releases. Although computationally efficient, the procedure required to add hydrologic-process algorithms to the original code was less than adequate. As a result, the architecture and modular structure of PRMS were redesigned to allow better integration and hydrologic-process algorithm-development capabilities. This new structure was the USGS Modular Modeling System (MMS), an integrated system of computer software developed for simulating a variety of water, energy, and biogeochemical processes that included PRMS.

The basic hydrologic-process algorithms in PRMS were maintained in the MMS version; however, the use of MMS enabled the addition of new process algorithms and the enhancement of many of the features and capabilities in the original PRMS. These additions included graphical systems and networked data systems that took advantage of increased computational power.

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Version 2.1 – January 17, 1996

This was the pre-MMS version of PRMS. It was precompiled for computers running the DOS and DG UNIX operating systems.

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Pre-version 2.0 – (1983 – 1996)

PRMS originally was developed as a single FORTRAN 77 program composed of algorithms encoded in subroutines, each representing an individual physical process of the hydrologic cycle.

For the processes related to temperature distribution, solar-radiation distribution, evaporation, transpiration, and surface runoff, two or more different algorithms were encoded, each representing a different conceptual approach. A specific algorithm was selected at run time by setting values in the input file. This modular-design concept enabled the creation and application of a model that was most appropriate for a given study and supported the long-term goal to expand the available process-simulation capabilities of PRMS.

This version of PRMS uses “punch card” formats for input files, line-printer-generated output plots, use of the USGS’s National Water Data Storage and Retrieval system, and the job-control language specifications necessary to execute PRMS on the Amdahl and Prime computer systems.