Penn State Integrated Hydrologic Model (PIHM)

Version: 2.X

Including:
Flux-PIHM

File Formats

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Civil & Environmental Engineering
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1 Input File Formats

PIHM is an integrated finite volume hydrologic model. It simulates channel routing, overland flow and groundwater flow in fully coupled scheme. It uses semi-discrete Finite Volume approach to discretize PDE (equations governing physical processes) into ODE to form a system of ODEs and solved with SUNDIALS[1].

PIHM incorporates an object-oriented model data structure which provides extensibility and efficient storage of data at the same time. PIHM v2.0 requires a total of eight [8] input files:

File		Purpose
0 projectName.txt	:	This file will have the project name as its content.
1 .mesh File	:	Spatial information of Nodes and Irregular Meshes (TINs)
2 .att File	:	Attribute defining different classes an element belongs to
3 .soil File	:	Soil properties
4 .geol	:	Geologic properties
5 .lc file	:	Vegetation parameters of different land cover types
6 .riv file	:	Spatial, geometry and material information of river segments
7 .forc file	:	All the forcing variables (forcing time-series)
8 .ibc file	:	Boundary condition information for elements
9 .para file	:	Control parameters (solver options; model modes; error control)
10. init	:	If initial condition input is through a file
11 .calib	:	Calibration parameters and process controls

This document describes the function of all the data files and the structure in which data is stored in details.

[1] SUite of Nonlinear and DIfferential/ALgebraic equation Solvers [http://www.llnl.gov/casc/sundials/]

2 projectName.txt

project Name is specified either on the command line while running the model, like

→ **./pihm** projectName

OR

it is specified in the file name **projectName.txt**.

Note: File has to be named **projectName.txt** and not the actual project name !. So if your project name is sc, then in the file projectName.txt you will have to write **sc** in it.

<u>File Structure:</u>

Project Name

3 .mesh File

Mesh file has all the irregular mesh (TIN) geometry information in it. It contains all the nodes and elements. For nodes, it records its location in space and for elements, it saves index of nodes of which elements comprise of and some topological relations in the form of its neighbor elements.

File Structure:

NumEle	NumNode					
Index	Node[0]	Node[1]	Node[2]	Nabr[0]	Nabr[1]	Nabr[2]
Index	Node[0]	Node[1]	Node[2]	Nabr[0]	Nabr[1]	Nabr[2]
.						
.	Repeat NumEle times…					
Index	X	Y	Zmin	Zmax		
Index	X	Y	Zmin	Zmax		
.						
.	Repeat NumNode times…					

Description:

Variable Name	Variable Type	Variable Description	Remarks	Units
NumEle	Integer	Total Number of Elements		
NumNode	Integer	Total Number of Nodes		
Index	Integer	Element Index		1 to …
Node[0]	Integer	1st Node of Element		
Node[1]	Integer	2nd Node of Element		
Node[2]	Integer	3rd Node of Element		
Nabr[0]	Integer	1st Neighbor of Element	Remark*1	
Nabr[1]	Integer	2nd Neighbor of Element	Remark*1	
Nabr[2]	Integer	3rd Neighbor of Element	Remark*1	
Index	Integer	Node Index		1 to …
X	double	x co-ordinate of node		Meters
Y	double	y co-ordinate of node		Meters
Zmin	double	bed elevation of node		Meters
Zmax	double	surface elevation of node		Meters

Remark*1: 0 represents no neighbor at the edge, it is the boundary of the watershed.

2. .att File

An att (attribute) file is a record which stores all the physical parameters class of each mesh elements such as soil type, land cover type, several forcing types. It allows efficient data storage.

File Structure:

Index	Soil	Geol	LC	IS_IC	Snw_IC	Srf_IC	Ust_IC	St_IC	Ppt	Tmp	RH	Wnd	Rn	G	VP	S	mF	BC[0]	BC[1]	BC[2]	mP
Index	Soil	Geol	LC	IS_IC	Snw_IC	Srf_IC	Ust_IC	St_IC	Ppt	Tmp	RH	Wnd	Rn	G	VP	S	mF	BC[0]	BC[1]	BC[2]	mP
.																					
.					Repeat NumEle times…																

Description:

Variable Name	Variable Type	Variable Description	Remarks	Units
Index	Integer	Element Index		1 to …
Soil	Integer	Soil Class		1 to …
Geol	Integer	Geology Class		1 to …
LC	Integer	Land Cover Class		1 to …
IS_IC	Integer	Interception Storage	Remark*1	Meters
Snw_IC	double	Snow Accumulation	Remark*1	Meters
Srf_IC	double	Surface flow State	Remark*1	Meters
Ust_IC	double	Unsaturated State	Remark*1	Meters
St_IC	double	Saturated State	Remark*1	Meters
Ppt	Integer	Precipitation Series	Remark*2	1 to …
Temp	Integer	Temperature Series	Remark*2	1 to …
RH	Integer	Rel. Humidity Series	Remark*2	1 to …
Wnd	Integer	Wind Velocity Series	Remark*2	1 to …
Rn	Integer	Solar Radiation Series	Remark*2	1 to …
G	Integer	Ground heat flux Series	Remark*2	1 to …
VP	Integer	Vapor Pressure		1 to …
S	Integer	Source/Sink		1 to …
mF	Integer	Melt Factor Series	Remark*2	1 to …
BC[0]	Integer	Boundary condition Type on edge		1 to …
BC[1]	Integer	……………………		1 to …
BC[2]	Integer	…………………..		1 to …
mP	Integer	Macropore present or not		1:Yes/ 0: No

Remark*1: If you flag (Init_type) in the .para file to use initial conditions in the .att file you need to have data values for these variables. Otherwise PIHM ignores these values.
Remark*2: Each watershed domain may be split into n partitions with each partition having its own variable series. For example, a watershed may have 4 NLDAS forcing cells. Thus, we have 4 series of T, P etc.

3. .soil File

All the hydrologic and hydraulic parameters related to different soil classes for surface/subsurface flow are stored in this file.

File Structure:

NumSoil								
Index	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	hAreaF	macKsatV
Index	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	hAreaF	macKsatV
.								
.	Repeat NumSoil times…							

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**	**Units**
NumSoil	Integer	Number of Soil Classes		
Index	Integer	Soil Class Number		1 to …
KsatV*	Double	Vertical Saturated Hydraulic Conductivity		Meters/day
ThetaS	Double	Porosity		m^3/m^3
ThetaR	Double	Residual Porosity		m^3/m^3
infD	Double	Top soil layer across which infiltration is calculated	Generally set to 0.1 m	m
Alpha*	Double	Van Genuchten Soil Parameter	Remark *1	Unit: m^{-1}
Beta*	Double	Van Genuchten Soil Parameter	Remark *1	Unit: dimensionless
hAreaF	Double	Horizontal Area Fraction of Macropore		Percent
macKsatV	Double	Vertical macropore Hydraulic conductivity		Meters/day

Remark*1: M. TH. VAN GENUCHTEN A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils
* ROSETTA: Software from United States Salinity Laboratory (USDA-ARS), Riverside, California can be a useful tool for getting these parameters.

* Note: Beta in $K_u - S$ van genuchten relationship is used as

$$K_u = S^{0.5}(1-(1-S^{\frac{\beta}{\beta-1}})^{\frac{\beta-1}{\beta}})^2$$

4. .geol File

All the hydrologic and hydraulic parameters related to different geologic classes for subsurface flow are stored in this file.

File Structure:

NumGeol										
Index	KsatH	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	vAreaF	macKsatH	macD
Index	KsatH	KsatV	ThetaS	ThetaR	infD	Alpha	Beta	vAreaF	macKsatH	macD
.										
.	Repeat NumGeol times…									

Description:

Variable Name	Variable Type	Variable Description	Remarks	Units
NumGeol	Integer	Number of Geology Classes		
Index	Integer	Geology Class Number		1 to …
KsatV	Double	Vertical Saturated Hydraulic Conductivity		m/day
ThetaS	Double	Porosity		m^3/m^3
ThetaR	Double	Residual Porosity		m^3/m^3
infD	Double	Top soil layer across which infiltration is calculated	Generally set to 0.1 m	m
Alpha	Double	Van Genuchten Soil Parameter	Remark *1	Unit: m^{-1}
Beta	Double	Van Genuchten Soil Parameter	Remark *1	Unit: dimensionless
vAreaF	Double	Vertical Area Fraction of Macropore		Percent
macKsatH	Double	Horizontal macropore Hydraulic conductivity		m/day
macD	Double	Macropore Depth		m

Remark*1: M. TH. VAN GENUCHTEN A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils
* ROSETTA: Software from United States Salinity Laboratory (USDA-ARS), Riverside, California can be a useful tool for getting these parameters.

* Note: Beta in $K_u - S$ van genuchten relationship is used as

$$K_u = S^{0.5}(1-(1-S^{\frac{\beta}{\beta-1}})^{\frac{\beta-1}{\beta}})^2$$

5. .lc File

Lc file contains several vegetation parameters corresponding to different land cover classes present in the modeling domain.

File Structure:

NumLC							
Index	LAImax	Rmin	Rs_ref	Albedo	VegFrac	n	RzD
Index	LAImax	Rmin	Rs_ref	Albedo	VegFrac	n	RzD
.							
.		Repeat NumLC times…					
.							
Index	LAImax	Rmin	Rs_ref	Albedo	VegFrac	n	RzD

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**	**Units**
NumLC	Integer	Number of Land Cover Classes		
Index	Integer	Land Cover Class Number		1 to …
LAImax	Double	Maximum LAI		m^2/m^2
Rmin	Double	Minimum Stomatal Resistance		Unit: day m^{-1}
Rs_ref	Double	Reference Stomatal Resistance		Unit: J day^{-1}
Albedo	Double	Albedo		Percent
VegFrac	Double	Vegetation Fraction		Percent
n	Double	Manning's Roughness Coefficient		day/$m^{1/3}$
RzD	Double	Root Zone Depth		m

6. .riv File

Topological information related to river segments (such as Node information; Left and Right Element) is stored in this file. Also different shape and material properties of river segments are provided. Other variables such as Initial and Boundary condition pertaining river segments are placed at the end of this file.

File Structure:

NumRiv										
Index	FromNode	ToNode	Down	LeftEle	RightEle	Shape	Material	IC	BC	Res
Index	FromNode	ToNode	Down	LeftEle	RightEle	Shape	Material	IC	BC	Res
.										
.		Repeat NumRiv times…								
"Shape"	NumShape									
Index	Depth	InterpOrd	WidCoeff							
Index	Depth	InterpOrd	WidCoedd							
.	Repeat NumShape times…									
"Material"	NumMat									
Index	n	Cwr	KsatH	KsatV	Bed					
Index	n	Cwr	KsatH	KsatV	Bed					
.	Repeat NumMat times…									
"IC"	NumIC									
Index	Value									
Index	Value									
Repeat NumIC times…										
Index	Value									
"BC"	NumBC									
Type	Index	Length								
Time	Value									
.										
Repeat Length times…										
.										
Time	Value									
Type	Index	Length								
Repeat NumBC times…										
Type	Index	Length								
"Res"	NumRes									

Description:

Variable Name	Variable Type	Variable Description	Remarks	Units
NumRiv	Integer	Number of River Segments		
Index	Integer	River Segment ID		1 to …
FromNode	Integer	From Node ID		1 to …
ToNode	Integer	To Node ID		1 to …
Down	Integer	Downstream Segment ID	Remark*1	1 to …
LeftEle	Integer	Left Element ID		1 to …
RightEle	Integer	Right Element ID		1 to …
Shape	Integer	Shape ID		1 to …
Material	Integer	Material ID		1 to …
IC	Integer	Initial Condition ID		1 to …
BC	Integer	Boundary Condition ID		1 to …
Res	Integer	Reservoir ID		1 to …
NumShape	Integer	Number of Shape Types		
Index	Integer	Shape ID		1 to …
Dummy	-	-		
Depth	Double	Depth of the River Segment		m
InterpOrder	Integer	Interpolation Order *	Remark*2	???
WidCoeff	Double	Width Coefficient *	width if a rectangular	???
NumMat	Integer	Number of Material Types		
Index	Integer	Material ID		1 to …
n	Double	Manning's Roughness Coefficient		day/m$^{1/3}$
Cwr	Double	Discharge Coefficient		???
KsatH	Double	Size Hydraulic Conductivity		m/day
KsatV	Double	Bed Hydraulic Conductivity		m/day
Bed	Double	Bed Depth		m
NumIC	Integer	Number of Initial Condition Types		
Index	Integer	Initial Condition ID		1 to …
Value	Double	Initial Condition Water Table	Depth???	m
NumBC	Integer	Number of Boundary Conditions		
Type	Integer	Boundary Condition Type	Remark*3	
Index	Integer	Boundary Condition ID		
Length	Integer	Length of BC Time Series		
Time	Double	Time		days
Value	Double	BC Value	(m or m/day)	????
NumRes	Integer	Number of Reservoirs		

Remark*1: -1 (Dirichlet Boundary Condition) -2 (Neumann BC) -3 (Zero-Depth-Gradient BC) -4 (Critical Depth BC)
Remark*2:
Remark*3:
* Interpolation Order (b) and Width Coefficient (a) are parameters defining relation between Width and Depth of a river segment as: [$D = a \times (W/2)^b$].

7. .forc File

Forc file contains all the forcing variable information (time series).

File Structure:

NumPrep	NumTemp	NumRH	NumWind	NumRn	NumG	NumVP	NumLC	NumMF	NumSS
"Prep"	Index	Length							
Time	Value								
Repeat Length times…									
Time	Value								
"Prep"	Index	Length							
Repeat NumPrep times…									
"Temp" *	Index	Length							
"RH" *	Index	Length							
"Wind" *	Index	Length	Height						
"Rn" *	Index	Length							
"VP" *	Index	Length							
"LAI" *	Index	Length	IsFactor						
"DH" *	Index	Length							
"MF" *	Index	Length							
“SS”*	Index	Length							

* Same as “Prep” time-series

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**	**Units**
NumPrep	Integer	Number of precipitation time-series	Remark*1	
NumTemp	Integer	Number of temperature time-series	Remark*1	
NumRH	Integer	Number of relative humidity time-series	Remark*1	
NumWind	Integer	Number of wind velocity time-series	Remark*1	
NumRn	Integer	Number of solar radiation time-series	Remark*1	
NumG	-	Number of Ground heat flux time-series		
NumVP	Integer	Number of vapor pressure time-series	Remark*1	
NumLAI	Integer	Number of LAI time-series	Remark*1	
NumMF	Integer	Number of melt factor time-series	Remark*1	
NumSS	Integer	Number of source/sink	Remark*1	
Index	Integer	Time-series ID		
Length	Integer	Number of time steps		
Time	Double	Time		days
Value	Double	Data value		
Height	Double	Height of wind velocity observation		m
IsFactor	Double	Interception Storage Factor		Unit: dimensionless

Remark*1: Each watershed domain may be split into n partitions with each partition having its own variable series. For example a watershed may have 4 NLDAS forcing cells. Thus we have 4 series of T, P etc.

8. .ibc File

IBC file contains all the information related to boundary conditions corresponding to elements.

File Structure:

NumBC1	NumBC2	
"BC1"	Index	Length
Time	Value	
Repeat Length times…		
Time	Value	
"BC1"	Index	Length
Repeat NumBC1 times…		
"BC1"	Index	Length
"BC2"	Index	Length
Time	Value	
Repeat Length times…		
Time	Value	
"BC2"	Index	Length
Repeat NumBC2 times…		
"BC2"	Index	Length

Description:

Variable Name	Variable Type	Variable Description	Remarks	Units
NumBC1	Integer	Number of Dirichlet BC		
NumBC2	Integer	Number of Neumann BC		
Index	Integer	Boundary Condition ID		1 to …
Length	Integer	Number of time steps		
Time	Double	Time		days
Value	Double	Value		(m or m/day)

9. .para File

Para file provides all the control data to the model. It contains solver options; model modes; also parameters that govern model error.

File Structure:

Verbose	Debug	Init_type								
PgwD	PsurfD	PsnowD	PrivStg							
PRech	PIsD	PusD								
Pet0	Pet1	Pet2								
Priv0	Priv1	Priv2	Priv3	Priv4	Priv5	Priv6	Priv7	Priv8	Priv9	Priv10
gwDInt	surfDInt	snowDint	rivStgInt							
RechInt	IsDInt	usDInt	etInt	rivFlxInt						
UsatMode	SatMode	RivMode								
Solver	GSType	MaxK	Delta							
AbsTol	RelTol	InitStep	MaxStep	ETstep						
StartTime	EndTime	Output								
a	b									

Description:

Variable Name	Variable Type	Variable Description	Remarks	Units
Verbose	Integer	Verbose mode?		Yes/No :: 1/0
Debug	Integer	Debug mode?		Yes/No :: 1/0
Init_type	Integer	State initialization type	Remark*1	Relax(0); AttFile(1); InitFile(3)
PgwD, PsurfD, PsnowD, PrivStg, Prech, PisD, PusD, Pet0, Pet1, Pet2	Integer	Print: Groundwater, Surface Water, Snow, River Stage, Rechage to Ground Water, Interception Storage, Unsaturated Storage, Interception Loss, Transpiration, Evaporation from Ground		Yes/No :: 1/0
Priv0, Priv1	Integer	Print: Longitudonal {Flow To, Flow from} a river element		Yes/No :: 1/0
Priv2, Priv3	Integer	Print: Lateral Overland Flow To a river element from {Left, Right}		Yes/No :: 1/0
Priv4, Priv5	Integer	Print: Lateral Groundwater Flow To a river element from {Left, Right}		Yes/No :: 1/0
Priv6	Integer	Print: Leakage/Base Flow To/From aquifer		Yes/No :: 1/0

Priv7, Priv8	Integer	Print: Longitudonal {Flow To, Flow from} a aquifer element beneath river		Yes/No :: 1/0
Priv9, Priv10	Integer	Print: Lateral Groundwater Flow To a aquifer element from {Left, Right} beneath river		Yes/No :: 1/0
gwDInt, surfDInt, snowDint, rivStgInt, RechInt, IsDInt, usDInt, etInt, rivFlxInt	Integer	Print Interval: Groundwater, Surface Water, Snow, River Stage, Rechage to Ground Water, Interception Storage, Unsaturated Storage, Evapotranspiration, River Flow		minutes
UsatMode	Integer	Unsaturation formulation	2	
SatMode	Integer	Saturation formulation	More details needed	Kinematic(1); Diffusion(2)
RivMode	Integer	River formulation	More details needed	Kinematic(1); Diffusion(2)
Solver	Integer	Cvode Solver Type	[see SUNDIALS manual]	Iterative(2)
GSType	Integer	GS Solver Type	[see SUNDIALS manual]	Modified(1); Classical(2)
MaxK	Integer	Max Krylov dimension	[see SUNDIALS manual]	
Delta	Double	GMRES convergence criterion	[see SUNDIALS manual]	
AbsTol	Double	Absolute Tolerance	[see SUNDIALS manual]	
RelTol	Double	Relative Tolerance	[see SUNDIALS manual]	
InitStep	Double	Initial time-step	[see SUNDIALS manual]	
MaxStep	Double	Maximum time-step	[see SUNDIALS manual]	
Etstep	Double	ET time-step		minutes
StartTime	Double	Simulation start time		minutes
EndTime	Double	Simulation end time		minutes
Output	Double	Output step-size		
a *	Double	Step-size factor	????	
b *	Double	Base step-size	?????	

* stepsize = b x a^i

Remark*1: Relax(0): It means groundwater table is below surface 0.1m. No storage in unsaturated zone and no pooling on surface.
AttFile(1):
InitFile(3): When you know initial conditions use this method.

10. .init File

Init file contains all the initial state condition variables.

IS	Snow	Overland	UnSat	Sat
IS	Snow	Overland	UnSat	Sat
Repeat NumEle times…				

RiverState	Sat Beneath River
RiverState	Sat Beneath River
……………………………..	
Repeat NumRiv times	

<u>Description:</u>

Variable Name	Variable Type	Variable Description	Remarks	Units
IS	double	Interception Storage		meters
Snow	double	Snow Storage		meters
Overland	double	Overland (Pooling Water)		meters
UnSat	double	Unsaturated Storage		meters
Sat	double	Saturated Storage		meters

11. .calib File

Calib File provides control for calibrating several physical parameters.

File Structure:

geolKsatH	geolKsatV	soilKsatV	macKsatH	macKsatV
infD	RzD	macD		
Porosity	Alpha	Beta		
vAreaF	hAreaf			
VegFrac	Albedo	Rough		
Precep	Temp			
Et0	Et1	Et2		
rivRough	rivKsatH	rivKsatV	rivBedThickness	
rivDepth	rivWidCoeff			

All the variables are the calibration multiple to the original corresponding variables.

Description:

Variable Name	Variable Type	Variable Description (Multiplicative Coefficients for)	Remarks	Units
infD	Double	Infiltration Depth	Multiplier	
RzD	Double	Root Zone Depth	Multiplier	
macD	Double	Macropore Depth	????	
Alpha, Beta	Double	Van genuchten parameters	Multiplier	
vAreaF, hAreaF	Double	Vertical, horizontal macropore area fraction	Multiplier	
VegFrac	Double	Vegetation Fraction	Multiplier	
Albedo	Double	Albedo	Multiplier	
Rough	Double	Manning's n	Multiplier	
Precep	Double	Precipitation	Multiplier	
Temp	Double	Temperature	Multiplier	
Et0	Double	Interception Loss	Multiplier	
Et1	Double	Transpiration	Multiplier	
Et2	Double	Evaporation from Ground	Multiplier	
rivRough	Double	River Manning's n	Multiplier	
rivKsatH, rivKsatV	Double	Conductivity of river walls and bed	Multiplier	
rivBedThickness	Double	River bed thickness	Multiplier	
rivDepth	Double	River depth	Multiplier	
rivWidCoeff	Double	River width coefficient	Multiplier	

Flux-PIHM

User's Guide

Last Updated: September 2, 2011

Pennsylvania State University, University Park, USA.

2 Flux-PIHM Input File Formats

Flux-PIHM is a fully-coupled land surface hydrologic model based on the Penn State Hydrologic Model (PIHM). Flux-PIHM requires a total of twelve input files:

File		Purpose
projectName.txt	:	This file contains the project name as its content.
.mesh File	:	Spatial information of nodes and irregular meshes (TINs)
.att File	:	Attribute defining different classes an element belongs to
.soil File	:	Soil properties of infiltration layer
.geol	:	Soil properties of aquifer layer below infiltration layer
.lc file	:	Vegetation parameters of different land cover types
.riv file	:	Spatial, geometry and material information of river segments
.forc file	:	All the forcing variables (forcing time-series)
.ibc file	:	Boundary condition information for elements
.para file	:	Control parameters (solver options; model modes; error control)
.init	:	If initial condition input is through a file
.calib	:	Calibration parameters and process controls

2.1 *Flux-PIHM* projectName.txt

Project name is specified either on the command line while running the model, like

./pihm projectName

or is specified in the file **projectName.txt**.

Note: File has to be named **projectName.txt** and not the actual project name. So if your project name is sc, then in the file projectName.txt you will have to write **sc** in it.

File Structure:

Project Name

2.2 *Flux-PIHM* .mesh File

Mesh file has all the irregular mesh (triangular irregular network; TIN) geometry information in it. It contains all the nodes and elements. For nodes, it records its location in space, and for elements it stores index of nodes of which elements comprise of and some topological relations in the form of its neighbor elements.

File Structure:

NumEle	NumNode					
Index	Node[0]	Node[1]	Node[2]	Nabr[0]	Nabr[1]	Nabr[2]
Index	Node[0]	Node[1]	Node[2]	Nabr[0]	Nabr[1]	Nabr[2]
Repeat NumEle times…						
Index	x	y	z_{min}	z_{max}		
Index	x	y	z_{min}	z_{max}		
Repeat NumNode times…						

Description:

Variable Name	Variable Type	Variable Description	Remarks
NumEle	Integer	Total number of elements	
NumNode	Integer	Total number of nodes	
Index	Integer	Element index	
Node[0]	Integer	1st node of element	
Node[1]	Integer	2nd node of element	
Node[2]	Integer	3rd node of element	
Nabr[0]	Integer	1st neighbor of element	0: boundary
Nabr[1]	Integer	2nd neighbor of element	0: boundary
Nabr[2]	Integer	3rd neighbor of element	0: boundary
Index	Integer	Node Index	
x	double	x coordinate of node	Unit: m
y	double	y coordinate of node	Unit: m
z_{min}	double	Bed elevation of node	Unit: m
z_{max}	double	Surface elevation of node	Unit: m

2.3 *Flux-PIHM* .att File

A .att (attribute) file is a record which stores all the physical parameters class of each mesh elements such as soil type, land cover type, several forcing types. It allows efficient data storage.

File Structure:

See next page.

Description:

Variable Name	Variable Type	Variable Description	Remarks
Index	Integer	Element Index	
Soil	Integer	Soil class	
Geol	Integer	Geology class	
LC	Integer	Land cover class	
IS_0	Integer	Interception storage	Initial condition
D_{snow0}	Double	Snow accumulation	Initial condition
h_{sfc0}	Double	Surface flow State	Initial condition
h_{soil0}	Double	Unsaturated state	Initial condition
h_{sat0}	Double	Saturated state	Initial condition
P_d	Integer	Precipitation series	
T	Integer	Temperature series	
RH	Integer	Relative humidity series	
U	Integer	Wind velocity series	
$S\downarrow$	Integer	Downward solar radiation series	
$L\downarrow$	Integer	Downward longwave radiation series	
P	Integer	Surface pressure	
S	Integer	Source/sink	
MF	Integer	Melt factor series	
BC[0]	Integer	Boundary condition type on edge	
BC[1]	Integer	Boundary condition type on edge	
BC[2]	Integer	Boundary condition type on edge	
MP	Integer	Macropore present or not	1:Yes/ 0: No

File Structure:

Index	Soil	Geol	LC	IS_0	D_{snow0}	h_{sfc0}	h_{soil0}	h_{sat0}	P_d	T	RH	U	$S\downarrow$	$L\downarrow$	P	S	MF	BC[0]	BC[1]	BC[2]	MP
Index	Soil	Geol	LC	IS_0	D_{snow0}	h_{sfc0}	h_{soil0}	h_{sat0}	P_d	T	RH	U	$S\downarrow$	$L\downarrow$	P	S	MF	BC[0]	BC[1]	BC[2]	MP
Repeat NumEle times…																					

2.4 *Flux-PIHM* .soil File

All the hydrologic and hydraulic parameters related to different soil classes for infiltration layer are stored in this file.

File Structure:

NumSoil								
Index	$K_{\mathrm{inf}V}$	Θ_s	Θ_r	D_{inf}	α	β	f_h	$K_{\mathrm{mac}V}$
Index	$K_{\mathrm{inf}V}$	Θ_s	Θ_r	D_{inf}	α	β	f_h	$K_{\mathrm{mac}V}$
Repeat NumSoil times…								

Description:

Variable Name	Variable Type	Variable Description	Remarks
NumSoil	Integer	Number of Soil Classes	
Index	Integer	Soil class number	Beginning with 1
$K_{\mathrm{inf}V}$	Double	Vertical saturated infiltration hydraulic conductivity	Unit: m day^{-1}
Θ_s	Double	Porosity	Unit: m^3 m^{-3}
Θ_r	Double	Residual porosity	Unit: m^3 m^{-3}
D_{inf}	Double	Top soil layer across which infiltration is calculated	Generally set to 0.1. Unit: m
α	Double	Van Genuchten soil parameter	Unit: m^{-1}
β	Double	Van Genuchten soil parameter	Unit: dimensionless
f_h	Double	Horizontal area fraction of macropore	Unit: m^2 m^{-2}
$K_{\mathrm{mac}V}$	Double	Vertical macropore hydraulic conductivity	Unit: m day^{-1}

* Note: β in van Genuchten soil water retention relationship is used as

$$K_u = S^{0.5}\left(1-\left(1-S^{\frac{\beta}{\beta-1}}\right)^{\frac{\beta-1}{\beta}}\right)^2$$

2.5 *Flux-PIHM* .geol File

All the hydrologic and hydraulic parameters related to different soil classes for aquifer layer below infiltration layer are stored here.

File Structure:

NumGeol									
Index	K_H	K_V	Θ_s	Θ_r	α	β	f_v	$K_{\mathrm{mac}V}$	D_{mac}
Index	K_H	K_V	Θ_s	Θ_r	α	β	f_v	$K_{\mathrm{mac}V}$	D_{mac}
Repeat NumGeol times…									

Description:

Variable Name	Variable Type	Variable Description	Remarks
NumGeol	Integer	Number of geology classes	
Index	Integer	Geology class number	Beginning with 1
K_H	Double	Horizontal saturated hydraulic conductivity	Unit: m day^{-1}
K_V	Double	Vertical saturated hydraulic conductivity	Unit: m day^{-1}
Θ_s	Double	Porosity	Unit: m^3 m^{-3}
Θ_r	Double	Residual porosity	Unit: m^3 m^{-3}
α	Double	Van genuchten soil parameter	Unit: m^{-1}
β	Double	Van genuchten soil parameter	Unit: dimensionless
f_v	Double	Vertical area fraction of macropore	Unit: m^2 m^{-2}
$K_{\mathrm{mac}V}$	Double	Horizontal macropore hydraulic conductivity	Unit: m day^{-1}
D_{mac}	Double	Macropore depth	Unit: m

2.6 *Flux-PIHM* .lc File

.lc file contains several vegetation parameters corresponding to different land cover classes present in the modeling domain.

File Structure:

NumLC													
Index	LAI_{max}	R_{min}	R_{gl}	a_{min}	a_{max}	e_{min}	e_{max}	z_{0min}	z_{0max}	GVF	n	D_{root}	h_s
Index	LAI_{max}	R_{min}	R_{gl}	a_{min}	a_{max}	e_{min}	e_{max}	z_{0min}	z_{0max}	GVF	n	D_{root}	h_s
Repeat NumLC times…													

Description:

Variable Name	Variable Type	Variable Description	Remarks
NumLC	Integer	Number of land cover classes	
Index	Integer	Land cover class number	
LAI_{max}	Double	Maximum LAI	Unit: m^2 m^{-2}
R_{min}	Double	Minimum stomatal resistance	Unit: day m^{-1}
R_{gl}	Double	Reference solar radiation	Unit: J day^{-1}
a_{min}	Double	Minimum albedo	Unit: dimensionless
a_{max}	Double	Maximum albedo	Unit: dimensionless
e_{min}	Double	Minimum emissivity	Unit: dimensionless
e_{max}	Double	Maximum emissivity	Unit: dimensionless
z_{0min}	Double	Minimum roughness length	Unit: m
z_{0max}	Double	Maximum roughness length	Unit: m
GVF	Double	Vegetation fraction	Unit: m^2 m^{-2}
n	Double	Manning's roughness coefficient	Unit: day $m^{-1/3}$
D_{root}	Double	Root zone depth	Unit: m
h_s	Double	Empirical parameter for vapor pressure deficit stress	Unit: dimensionless

2.7 *Flux-PIHM* .riv File

Topological information related to river segments (such as Node information; Left and Right Element) is stored in this file. Also different shape and material properties of river segments are provided. Other variables such as Initial and Boundary condition pertaining river segments are placed at the end of this file.

File Structure:

NumRiv										
Index	ND_{from}	ND_{to}	ND_{down}	ELE_{left}	ELE_{right}	Shape	Material	IC	BC	Res
Index	ND_{from}	ND_{to}	ND_{down}	ELE_{left}	ELE_{right}	Shape	Material	IC	BC	Res
Repeat NumRiv times…										
"Shape"	N_{shape}									
Index	D_{riv}	O_{int}	C_{wid}							
Index	D_{riv}	O_{int}	C_{wid}							
Repeat N_{shape} times…										
"Material"	N_{mat}									
Index	n_{riv}	C_{wr}	K_{rivH}	K_{rivV}	$\underline{h}_{rivbed}$					
Index	n_{riv}	C_{wr}	K_{rivH}	K_{rivV}	$\underline{h}_{rivbed}$					
Repeat N_{mat} times…										
"IC"	N_{IC}									
Index	Value									
Repeat N_{IC} times…										
Index	Value									
"BC"	N_{BC}									
Type	Index	Length								
Time	Value									
Repeat Length times…										
Time	Value									
Type	Index	Length								
Repeat N_{BC} times…										
Type	Index	Length								
"Res"	N_{res}									

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumRiv	Integer	Number of river segments	
Index	Integer	River segment ID	Beginning with 1
ND_{from}	Integer	From node ID	
ND_{to}	Integer	To node ID	
ND_{down}	Integer	Downstream segment ID	
ELE_{left}	Integer	Left element ID	
ELE_{right}	Integer	Right element ID	
Shape	Integer	Shape ID	
Material	Integer	Material ID	
IC	Integer	Initial condition ID	
BC	Integer	Boundary condition ID	
Res	Integer	Reservoir ID	
N_{shape}	Integer	Number of shape types	
Index	Integer	Shape ID	Beginning with 1
D_{riv}	Double	Depth of the river segment	
O_{int}	Integer	Interpolation order *	1 if a rectangular
C_{wid}	Double	Width coefficient *	Width if a rectangular
N_{mat}	Integer	Number of material types	
Index	Integer	Material ID	Beginning with 1
n_{riv}	Double	Manning's roughness coefficient	Unit: day $m^{-1/3}$
C_{wr}	Double	Discharge coefficient	
K_{rivH}	Double	Side hydraulic conductivity	Unit: m day^{-1}
K_{rivV}	Double	Bed hydraulic conductivity	Unit: m day^{-1}
$\underline{h}_{rivbed}$	Double	Bed depth	Unit: m
N_{IC}	Integer	Number of initial condition types	
Index	Integer	Initial condition ID	Beginning with 1
Value	Double	Intial condition water table	
N_{BC}	Integer	Number of boundary conditions	
Type	Integer	Boundary condition type	
Index	Integer	Boundary condition ID	
Length	Integer	Length of BC time series	
Time	Double	Time	
Value	Double	BC value	Unit: m or m day^{-1}
N_{res}	Integer	Number of reservoirs	

* Interpolation Order (b) and Width Coefficient (a) are parameters defining relation between Width and Depth of a river segment as:

$$D = ax\left(\frac{W}{2}\right)^{b}.$$

2.8 *Flux-PIHM* .forc File

.forc file contains all the forcing variable information (time series).

File Structure:

N_{Pd}	N_T	N_{RH}	N_U	$N_{S\downarrow}$	$N_{L\downarrow}$	N_P	N_{LC}	N_{MF}	N_{SS}
"Prep"	Index	Length							
Time	Value								
Repeat Length times									
Time	Value								
"Prep"	Index	Length							
Repeat N_{Pd} times…									
"Temp" *	Index	Length							
"RH" *	Index	Length							
"Wind" *	Index	Length	Height						
"S↓" *	Index	Length							
"L↓" *	Index	Length							
"P" *	Index	Length							
"LAI" *	Index	Length	F_{IS}						
"RL" *	Index	Length							
"MF" *	Index	Length							
"SS"*	Index	Length							

* Same as "Prep" time-series

Description:

Variable Name	Variable Type	Variable Description	Remarks
N_{Pd}	Integer	Number of precipitation time-series	Unit of P_d: m day^{-1}
N_T	Integer	Number of temperature time-series	Unit of T: °C
N_{RH}	Integer	Number of relative humidity time-series	Unit of RH: 100%
N_U	Integer	Number of wind speed time-series	Unit of U: m day^{-1}
$N_{S\downarrow}$	Integer	Number of solar radiation time-series	Unit of $S\downarrow$: J day^{-1}
$N_{L\downarrow}$	Integer	Number of thermal radiation time-series	Unit of $L\downarrow$: J day^{-1}
N_P	Integer	Number of surface pressure time-series	Unit of P: Pa
N_{LC}	Integer	Number of land cover time-series	Unit of LAI: m^{-2} m^{-2}
N_{MF}	Integer	Number of melt factor time-series	
N_{SS}	Integer	Number of source/sink	
Index	Integer	Time-series ID	
Length	Integer	Number of time steps	
Time	Time string	Time	YYYY-MM-DD HH:MM:SS
Value	Double	Data value	
Height	Double	Height of wind velocity observation	Unit: m
F_{IS}	Double	Interception storage factor	Unit: dimensionless

2.9 *Flux-PIHM* .ibc File

IBC file contains all the information related to boundary conditions corresponding to elements.

File Structure:

NumBC1	NumBC2	
"BC1"	Index	Length
Time	Value	
Repeat Length times…		
Time	Value	
"BC1"	Index	Length
Repeat NumBC1 times…		
"BC1"	Index	Length
"BC2"	Index	Length
Time	Value	
Repeat Length times…		
Time	Value	
"BC2"	Index	Length
Repeat NumBC2 times…		
"BC2"	Index	Length

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
NumBC1	Integer	Number of Dirichlet BC	
NumBC2	Integer	Number of Neumann BC	
Index	Integer	Boundary Condition ID	
Length	Integer	Number of time steps	
Time	Double	Time	
Value	Double	Value	Unit: m or m day^{-1}

2.10 *Flux-PIHM* .para File

Para file provides all the control data to the model. It contains solver options; model modes; also parameters that govern model error.

File Structure:

Verbose	Debug	Init_type							
PgwD	PsurfD	PsnowD	PrivStg						
PRech	PIsD	PusD							
Pet0	Pet1	Pet2	Plsv						
Priv0	Priv1	Priv2	Priv3	Priv4	Priv5	Priv6	Priv7	Priv8	Priv9
gwDInt	surfDInt	snowDint	rivStgInt						
RechInt	IsDInt	usDInt	etInt	rivFlxInt					
UsatMode	SatMode	RivMode							
Solver	GSType	MaxK	Delta						
AbsTol	RelTol	InitStep	MaxStep	ETstep					
StartTime	EndTime	Output							
a	b								

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
Verbose	Integer	Verbose mode?	Yes/No :: 1/0
Debug	Integer	Debug mode?	Yes/No :: 1/0
Init_type	Integer	State initialization type	Relax(0); AttFile(1); InitFile(3)
PgwD, PsurfD, PsnowD, PrivStg, Prech, PisD, PusD, Pet0, Pet1, Pet2, Plsv	Integer	Print: Groundwater, Surface Water, Snow, River Stage, Recharge to Ground Water, Interception Storage, Unsaturated Storage, Interception Loss, Transpiration, Evaporation from Ground, Land Surface Variables	Yes/No :: 1/0
Priv0, Priv1	Integer	Print: Longitudonal {Flow To, Flow from} a river element	Yes/No :: 1/0
Priv2, Priv3	Integer	Print: Lateral Overland Flow To a river element from {Left, Right}	Yes/No :: 1/0
Priv4, Priv5	Integer	Print: Lateral Groundwater Flow To a river element from {Left, Right}	Yes/No :: 1/0
Priv6	Integer	Print: Leakage/Base Flow To/From aquifer	Yes/No :: 1/0
Priv7, Priv8	Integer	Print: Longitudonal {Flow To, Flow from} a aquifer element beneath river	Yes/No :: 1/0
Priv9	Integer	Print: Lateral Groundwater Flow To a aquifer element from {Left, Right} beneath river	Yes/No :: 1/0

gwDInt, surfDInt, snowDint, rivStgInt, RechInt, IsDInt, usDInt, etInt, rivFlxInt	Integer	Print Interval: Groundwater, Surface Water, Snow, River Stage, Rechage to Ground Water, Interception Storage, Unsaturated Storage, Evapotranspiration, River Flow	Note: Unit is in minutes
UsatMode	Integer	Unsaturation formulation	2
SatMode	Integer	Saturation formulation	Kinematic(1); Diffusion(2)
RivMode	Integer	River formulation	Kinematic(1); Diffusion(2)
Solver	Integer	Cvode Solver Type	Iterative(2)
GSType	Integer	GS Solver Type	Modified(1); Classical(2)
MaxK	Integer	Max Krylov dimension	
Delta	Double	GMRES convergence criterion	
AbsTol	Double	Absolute Tolerance	
RelTol	Double	Relative Tolerance	
InitStep	Double	Initial time-step	[see SUNDIALS manual]
MaxStep	Double	Maximum time-step	[see SUNDIALS manual]
Etstep	Double	ET time-step	
StartTime	Time string	Simulation start time	YYYY-MM-DD HH:MM:SS
EndTime	Time string	Simulation end time	YYYY-MM-DD HH:MM:SS
Output	Double	Output step-size	
a *	Double	Step-size factor	
b *	Double	Base step-size	

* stepsize = b x a^i

2.11 *Flux-PIHM* .init File

.init file contains all the initial state condition variables.

IS	D_{snow}	h_{sfc}	h_{soil}	h_{sat}	T_{sfc}	T_{z1}	T_{z2}	T_{z3}	T_{z4}	Θ_{z1}	Θ_{z2}	Θ_{z3}	Θ_{z4}
IS	D_{snow}	h_{sfc}	h_{soil}	h_{sat}	T_{sfc}	T_{z1}	T_{z2}	T_{z3}	T_{z4}	Θ_{z1}	Θ_{z2}	Θ_{z3}	Θ_{z4}
.													
Repeat NumEle times…													

h_{riv}	h_{satriv}	D_{snowriv}
h_{riv}	h_{satriv}	D_{snowriv}
….		
Repeat NumRiv times		

Description:

Variable Name	**Variable Type**	**Variable Description**	**Remarks**
IS	Double	Interception storage	Unit: m
D_{snow}	Double	Depth of snow	Unit: m
h_{sfc}	Double	Surface water	Unit: m
h_{soil}	Double	Unsaturated state	Unit: m
h_{sat}	Double	Saturated state	Unit: m
T_{sfc}	Double	Land surface temperature	Unit: °C
$T_{z1\text{-}4}$	Double	Soil temperature at different layers	Unit: °C
$\Theta_{z1\text{-}4}$	Double	Soil moisture at different layers	Unit: $m^3\ m^{-3}$
h_{riv}	Double	River state	Unit: m
h_{satriv}	Double	Saturated state beneath river	Unit: m
D_{snowriv}	Double	Snow depth over river	Unit: m

2.12 *Flux-PIHM* .calib File

Calibration file provides control for calibrating several physical parameters. All the variables are the calibration multiple to the original corresponding variables.

File Structure:

K_H	K_V	$K_{\text{inf}V}$	$K_{\text{mac}H}$	$K_{\text{mac}V}$
D_{inf}	D_{root}	D_{mac}		
Θ	α	β		
f_V	f_H			
GVF	a	n		
P_d	T			
E_c	E_t	E_{dir}		
n_{riv}	$K_{\text{riv}H}$	$K_{\text{riv}V}$	$\underline{h}_{\text{rivbed}}$	
D_{riv}	C_{rivwid}			
TF	IS_{max}			
R_{min}	C_{zil}	fx_{soil}	fx_{canopy}	
R_{gl}	h_s	T_{ref}	Θ_{ref}	Θ_w

Description:

Variable Name	Variable Type	Variable Description (Multiplicative Coefficients for)	Remarks
K_H, K_V	Double	Horizontal and vertical saturation conductivities	
$K_{\text{inf}V}$	Double	Vertical infiltration saturation conductivities	
$K_{\text{mac}H}$, $K_{\text{mac}H}$	Double	Horizontal and vertical macropore conductivities	
D_{inf}	Double	Infiltration depth	
D_{root}	Double	Root zone depth	
D_{mac}	Double	Macropore depth	
Θ	Double	Porosity	
α, β	Double	Van Genuchten parameters	
f_V, f_H	Double	Vertical and horizontal macropore area fraction	
GVF	Double	Vegetation fraction	
a	Double	Albedo	
n	Double	Manning's n	
P_d	Double	Precipitation	
T	Double	Temperature	
E_c	Double	Canopy evaporation	
E_t	Double	Transpiration	
E_{dir}	Double	Soil evaporation	
n_{riv}	Double	River Manning's n	
$K_{\text{riv}H}$	Double	Conductivity of river walls and bed	
$\underline{h}_{\text{rivbed}}$	Double	River bed thickness	

D_{riv}	Double	River depth	
C_{rivwid}	Double	River width coefficient	
TF	Double	Through fall	
IS	Double	Maximum interception storage	
R_{min}	Double	Minimum Stomatal Resistance	
C_{zil}	Double	Zilitinkevich parameter	
fx_{soil}	Double	Soil evaporation rate	
fx_{canopy}	Double	Canopy evaporation rate	
R_{gl}	Double	Reference solar radiation	
h_s	Double	Empirical parameter for vapor pressure deficit stress	
T_{ref}	Double	Optimal temperature for transpiration	
Θ_{ref}	Double	Field capacity	
Θ_w	Double	Wilting point	

3 Flux-PIHM Output file formats

Flux-PIHM stores model outputs in text formats. Each output variable is stored in one output file, which contains the time series of model grid elements, or river segments, or both.

The first column of output files is the time stamp of output time step, in the format of "YYYY-MM-DD HH:MM". The time stamp is followed by output variables from the 1^{st} element (or river segment) to the last element (or river segment). The output files with grid elements have the following format:

Time stamp of 1^{st} time step	Output from 1^{st} element	Output from 2^{nd} element	…	Output from $N_{ele}{}^{th}$ element
…				
Time stamp of last time step	Output from 1^{st} element	Output from 2^{nd} element	…	Output from $N_{ele}{}^{th}$ element

The output files with river segments have the following format:

Time stamp of 1^{st} time step	Output from 1^{st} river segment	Output from 2^{nd} river segment	…	Output from $N_{riv}{}^{th}$ segment
…				
Time stamp of 1^{st} time step	Output from 1^{st} river segment	Output from 2^{nd} river segment	…	Output from $N_{riv}{}^{th}$ segment

The output files with both elements and river segments have the following format:

Time stamp of 1^{st} time step	Output from 1^{st} element	…	Output from $N_{ele}{}^{th}$ element	Output from 1^{st} river segment	…	Output from $N_{riv}{}^{th}$ segment
…						
Time stamp of 1^{st} time step	Output from 1^{st} element	…	Output from $N_{ele}{}^{th}$ element	Output from 1^{st} river segment	…	Output from $N_{riv}{}^{th}$ segment

The contents in each output files are:

Output file	Contents	Unit	Number of columns
.rivFlx0, .rivFlx1	Longitudinal flow to (from) a river segment	m^3 day^{-1}	N_{riv}+1
.rivFlx2, .rivFlx3	Lateral overland flow to a river element from left (right)	m^3 day^{-1}	N_{riv}+1

.rivFlx4, .rivFlx5	Lateral groundwater flow to a river element form left (right)	$m^3\ day^{-1}$	N_{riv}+1
.rivFlx6	Leakage flow to aquifer	$m^3\ day^{-1}$	N_{riv}+1
.rivFlx7, .rivFlx8	Longitudinal flow to (from) an aquifer element beneath river	$m^3\ day^{-1}$	N_{riv}+1
.rivFlx9, .rivFlx10	Lateral groundwater flow to an aquifer element from left (right) beneath river	$m^3\ day^{-1}$	N_{riv}+1
.GW	Groundwater level	m	N_{ele}+N_{riv}+1
.unsat	Soil water storage	m	N_{ele}+1
.stage	River stage	m	N_{riv}+1
.surf	Surface water	m	N_{ele}+1
.Rech	Recharge	$m\ day^{-1}$	N_{ele}+1
.snow	Snow depth	m	N_{ele}+N_{riv}+1
.is	Interception storage	m	N_{ele}+1
.et0	Canopy evaporation	$m\ day^{-1}$	N_{ele}+1
.et1	Transpiration	$m\ day^{-1}$	N_{ele}+1
.et2	Soil evaporation	$m\ day^{-1}$	N_{ele}+1
.G	Ground heat flux	$W\ m^{-2}$	N_{ele}+1
.SH	Sensible heat flux	$W\ m^{-2}$	N_{ele}+1
.LE	Latent heat flux	$W\ m^{-2}$	N_{ele}+1
.TS	Land surface temperature	˚C	N_{ele}+1
.TSOIL5	Soil temperature at 5 cm	˚C	N_{ele}+1
.TSOIL25	Soil temperature at 25 cm	˚C	N_{ele}+1
.TSOIL70	Soil temperature at 70 cm	˚C	N_{ele}+1
.TSOIL150	Soil temperature at 150 cm	˚C	N_{ele}+1
.SM5	Soil water content at 5 cm	$m^3\ m^{-3}$	N_{ele}+1
.SM25	Soil water content at 25 cm	$m^3\ m^{-3}$	N_{ele}+1
.SM70	Soil water content at 70 cm	$m^3\ m^{-3}$	N_{ele}+1
.SM150	Soil water content at 150 cm	$m^3\ m^{-3}$	N_{ele}+1
.SMbot	Soil water content at last layer	$m^3\ m^{-3}$	N_{ele}+1