Editable Distributed Hydrological Model

Kan Lei

2021-04-14

Contents

```
## [[1]]
## [[1]][[1]]
## NULL
##
## [[1]][[2]]
## NULL
##
## [[1]][[3]]
## NULL
##
##
## [[2]]
## [[2]][[1]]
## NULL
##
## [[2]][[2]]
## NULL
##
##
## [[3]]
## [[3]][[1]]
## NULL
##
## [[3]][[2]]
## NULL
##
##
## [[4]]
## [[4]][[1]]
## NULL
##
##
## [[5]]
## [[5]][[1]]
```

```
## NULL
##
##
## [[6]]
## [[6]][[1]]
## NULL
##
##
## [[7]]
## [[7]][[1]]
## NULL
##
## [[7]][[2]]
## NULL
##
##
## [[8]]
## [[8]][[1]]
## NULL
##
## [[8]][[2]]
## NULL
##
## [[8]][[3]]
## NULL
##
## [[8]][[4]]
## NULL
##
## [[8]][[5]]
## NULL
##
##
## [[9]]
## [[9]][[1]]
## NULL
##
##
## [[10]]
## [[10]][[1]]
## NULL
##
## [[10]][[2]]
## NULL
```

The Document and the EDHM Package

The Document

This document is the use guide for EDHM and some other information about the hydrological models (**HM**) building.

EDHM

EDHM is a R package for hydrological models in order to simplify the models building, specially the distributed hydrological model. In the package contain many complete **MODEL** that can used directly, and many **MODULE** that can a new MODEL to building. All of the MODELs and MODULEs are build with matrix-arithmetic, that can good deal with the distributed situation. In the package there are many tools to calibrate the parameters or build a new MODEL or a new MODULE. The Package is only in GitHub published, for the first time use, please install the package EDHM and HMtools use the following code:

```
install.packages("devtools")
devtools::install_github("LuckyKanLei/HMtools")
devtools::install_github("LuckyKanLei/EDHM")
```

The summary of the Processes and Modules show in the following table:

Process	Module
ReferenceET	[ReferenceET.Hargreaves](#ReferenceET.Hargreaves) | [ReferenceET.Linacre](#
ActualET	[ActualET.Gr4j](#ActualET.Gr4j) | [ActualET.Vic](#ActualET.Vic)
SNOW	[SNOW.17](#SNOW.17) | [SNOW.Ddf](#SNOW.Ddf)
BASEFLOW	[BASEFLOW.ARNO](#BASEFLOW.ARNO)
INTERCEPTION	[INTERCEPTION.Gash](#INTERCEPTION.Gash)
InfiltratRat	[InfiltratRat.GreenAmpt](#InfiltratRat.GreenAmpt)
Infiltration	[Infiltration.OIER](#Infiltration.OIER) | [Infiltration.SER](#Infiltration.SER)
RUNOFF	[RUNOFF.Gr4j](#RUNOFF.Gr4j) | [RUNOFF.OIER](#RUNOFF.OIER) | [RU
GROUNDWATER	[GROUNDWATER.Vic](#GROUNDWATER.Vic)
ROUTE	[ROUTE.G2RES](#ROUTE.G2RES) | [ROUTE.Gr4j](#ROUTE.Gr4j)

Chapter 1

Basic Concept

1.1 Hydrological Cycle

Process

1.2 Important Concept of EDHM

Process

Method

Module

Model

Run_Model

Evaluate

Calibrate

1.3 Data and Parameter

1.3.1 Variable naming

1.3.2 Data Structure

1.3.3 Data or Parameter

Chapter 2

Model Use and Develop

Choose a Model

virtue: convenience

shortage: poor adaptability

2.1 Model Structure or Concept

Design a Model

2.2 Use Model with a MODEL or Run_MODEL

2.2.1 Check the InData list

2.2.2 Data Preparation

2.2.3 Evaluate

2.2.4 Calibrate

2.3 Copuling a new Model with MODULE

2.3.1 Choose MODULE

2.3.2 Set the Data-FLow

2.3.3 Build the MODEL and Run_MODEL

2.4 Design a new MODULE

2.4.1 Method and Formula

2.4.2 Coding the Inhalt

2.4.3 Set In/OutData and Parameter

Here is a review of existing methods.

Chapter 3

Modules

Overview of ***Modules***

Process	Module
ReferenceET	[ReferenceET.Hargreaves](#ReferenceET.Hargreaves) | [ReferenceET.Linacre](#ReferenceET
ActualET	[ActualET.Gr4j](#ActualET.Gr4j) | [ActualET.Vic](#ActualET.Vic)
SNOW	[SNOW.17](#SNOW.17) | [SNOW.Ddf](#SNOW.Ddf)
BASEFLOW	[BASEFLOW.ARNO](#BASEFLOW.ARNO)
INTERCEPTION	[INTERCEPTION.Gash](#INTERCEPTION.Gash)
InfiltratRat	[InfiltratRat.GreenAmpt](#InfiltratRat.GreenAmpt)
Infiltration	[Infiltration.OIER](#Infiltration.OIER) | [Infiltration.SER](#Infiltration.SER)
RUNOFF	[RUNOFF.Gr4j](#RUNOFF.Gr4j) | [RUNOFF.OIER](#RUNOFF.OIER) | [RUNOFF.SER]
GROUNDWATER	[GROUNDWATER.Vic](#GROUNDWATER.Vic)
ROUTE	[ROUTE.G2RES](#ROUTE.G2RES) | [ROUTE.Gr4j](#ROUTE.Gr4j)

3.1 ReferenceET

3.1.1 ReferenceET.Hargreaves

This Module reference to the Literature: Reference Crop Evapotranspiration from Temperature (George H. Hargreaves and Zohrab A. Samani, 1985).

InData

Param

OutData

Return to the Overview of Modules.

Group	Variable	Unit	Description
MetData	TAir	Cel	Average Air temperature in Timestep
	TMax	Cel	Maximal Air temperature in one day
	TMin	Cel	Minimul Air temperature in one day
GeoData	Latitude	deg	Latitude
TimeData	NDay	–	Day nummer in one year

Paramter	Min	Max	Unit	Description
PeriodN	1	9999	–	The number of Step
GridN	1	9999	–	The nummber of effektive Grids

Group	Variable	Unit	Description
Evatrans	RET	mm	Reference evapotranspiration

3.1.2 ReferenceET.Linacre

This Module reference to the Literature: A simple formula for estimating evaporation rates in various climates, using temperature data alone (Linacre, 1977).

InData

Group	Variable	Unit	Description
MetData	TAir	Cel	Average Air temperature in Timestep
	Actual_vapor_press	mPa	Actual vapor press
GeoData	Latitude	deg	Latitude
	Elevation	m	Elevation
TimeData	NDay	–	Day nummer in one year

Param

Paramter	Min	Max	Unit	Description
PeriodN	1	9999	–	The number of Step
GridN	1	9999	–	The nummber of effektive Grids

OutData

Group	Variable	Unit	Description
Evatrans	RET	mm	Reference evapotranspiration

Return to the Overview of Modules.

3.1.3 ReferenceET.PenMon

This Module reference to the Literature: Step by Step Calculation of the Penman-Monteith Evapotranspiration (FAO-56) (Lincoln Zotarelli, 2014).

InData

Group	Variable	Unit	Description
MetData	TAir	Cel	Average Air temperature in Timestep
	TMax	Cel	Maximal Air temperature in one day
	TMin	Cel	Minimul Air temperature in one day
	RelativeHumidity	%	Relative Humidity, not greater than 100
	WindSpeed	m/s	Average Wind Speed
	WindH	m	The hight to mess the WindSpeed
	SunHour	h	Sunshine duration in one day
GeoData	Latitude	deg	Latitude
	Elevation	m	Elevation
TimeData	NDay	–	Day nummer in one year

Param

Paramter	Min	Max	Unit	Description
PeriodN	1	9999	–	The number of Step
GridN	1	9999	–	The nummber of effektive Grids

OutData

Group	Variable	Unit	Description
Evatrans	RET	mm	Reference evapotranspiration

Return to the Overview of Modules.

3.2 ActualET

3.2.1 ActualET.Gr4j

This Module reference to the Literature: Improvement of a parsimonious model for streamflow simulation (Perrin et al., 2003).

InData

Group	Variable	Unit	Description
Evatrans	RET	mm	Reference evapotranspiration
Ground	MoistureVolume	mm	Moisture volume
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

OutData

Return to the Overview of Modules.

Paramter	Min	Max	Unit	Description
Gr4j_X1	0.1	9.99	mm	NA

Group	Variable	Unit	Description
Evatrans	AET	mm	Actual evapotranspiration
Prec	Precipitation	mm	Precipitation, summe of rain and snow

3.2.2 ActualET.Vic

This Module reference to the Literature: none (**?**).

InData

Group	Variable	Unit	Description
Aerodyna	AerodynaResist	s/m	Aerodyna Resist
	ArchitecturalResist	s/m	Architectural Resist
	StomatalResist	s/m	Stomatal Resist
Canopy	StorageCapacity	mm	Canopy Storage Capacity for Intercept and Evaporation f
Evatrans	RET	mm	Reference evapotranspiration
Ground	MoistureVolume	mm	Moisture volume
	MoistureCapacityMax	mm	Maximal Moisture Capacity
Intercept	Interception	mm	Interception in Canopy
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

Paramter	Min	Max	Unit	Description
SoilMoistureCapacityB	0	0	–	–

OutData

Group	Variable	Unit	Description
Evatrans	EvaporationCanopy	mm	Evaporation from Canopy
	Transpiration	mm	Transpiration (water from Root layer of vegetation)
	EvaporationLand	mm	Evaporation from Landsurface (sometimes cotain the Evapo

Return to the Overview of Modules.

3.3 SNOW

3.3.1 SNOW.17

This Module reference to the Literature: National Weather Service river forecast system: snow accumulation and ablation model (Anderson, 1973).

InData

Group	Variable	Unit	Description
MetData	TAir	Cel	Average Air temperature in Timestep
Snow	Ice_Volume	mm	Soild Ice Volume, not depth
	Liquid_Volume	mm	Liquid Volume
	SN17_ATI	–	–
	SN17_HD	mm	–
Prec	SnowFall	mm	Snow
	RainFall	mm	Rain
GeoData	Elevation	m	Elevation
TimeData	NDay	–	Day nummer in one year

Param

Paramter	Min	Max	Unit	Description
SN17_SCF	0.70	1.40	–	Snowfall correction factor
SN17_MFMAX	0.50	2.00	mm/6hCel	Maximum melt factor considered to occur on June 21
SN17_MFMIN	0.05	0.49	mm/6hCel	Minimum melt factor considered to occur on December 21
SN17_UADJ	0.03	0.19	mm/6hCel	The average wind function during rain-on-snow periods
SN17_NMF	0.05	0.50	mm/6hCel	Maximum negative melt factor
SN17_TIPM	0.10	1.00	–	Antecedent snow temperature index
SN17_PXTEMP	-2.00	2.00	Cel	Temperature that separates rain from snow
SN17_MBASE	0.00	1.00	Cel	Base temperature for non-rain melt factor
SN17_PLWHC	0.02	0.30	–	Percent of liquid–water capacity
SN17_DAYGM	0.00	0.30	mm/d	Daily melt at snow–soil interface
TimeStepSec	1.00	9999.00	s	Second pro Step

OutData

Group	Variable	Unit	Description
Snow	Ice_Volume	mm	Soild Ice Volume, not depth
	Liquid_Volume	mm	Liquid Volume
	SN17_ATI	–	–
	SN17_HD	mm	–
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Return to the Overview of Modules.

3.3.2 SNOW.Ddf

This Module reference to the Literature: none (**?**).

InData

Param

Group	Variable	Unit	Description
Ground	MoistureVolume	mm	Moisture volume
Snow	Volume	mm	Summe Volume of Ice and liquid water, not depth
Prec	SnowFall	mm	Snow
	RainFall	mm	Rain

Paramter	Min	Max	Unit	Description
Factor_Day_degree	0	0	–	–

OutData

Group	Variable	Unit	Description
Snow	Volume	mm	Summe Volume of Ice and liquid water, not depth
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Return to the Overview of Modules.

3.4 BASEFLOW

3.4.1 BASEFLOW.ARNO

This Module reference to the Literature: LARGE AREA HYDROLOGIC MODELING AND ASSESSMENT PART I: MODEL DEVELOPMENT (Arnold et al., 1998).

InData

Group	Variable	Unit	Description
Ground	MoistureVolume	mm	Moisture volume
	MoistureCapacityMax	mm	Maximal Moisture Capacity

Param

Paramter	Min	Max	Unit	Description
ExponentARNOBase	0	0	–	–
ARNOBaseThresholdRadio	0	0	–	–
DrainageLossMax	0	0	–	–
DrainageLossMin	0	0	–	–

OutData

Group	Variable	Unit	Description
Ground	BaseFlow	mm	Base Flow

Return to the Overview of Modules.

3.5 INTERCEPTION

3.5.1 INTERCEPTION.Gash

This Module reference to the Literature: An analytical model of rainfall interception by forests (Gash, 1979).

InData

Group	Variable	Unit	Description
Canopy	StorageCapacity	mm	Canopy Storage Capacity for Intercept and Evaporation from Canopy
Evatrans	EvaporationCanopy	mm	Evaporation from Canopy
Intercept	Interception	mm	Interception in Canopy
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

Paramter	Min	Max	Unit	Description
CoefficientFreeThroughfall	0	0	–	–

OutData

Group	Variable	Unit	Description
Intercept	Interception	mm	Interception in Canopy
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Return to the Overview of Modules.

3.6 InfiltratRat

3.6.1 InfiltratRat.GreenAmpt

This Module reference to the Literature: Drainage to a water table analysed by the Green-Ampt approach (Youngs and Aggelides, 1976).

InData

Group	Variable	Unit	Description
Ground	MoistureVolume	mm	Moisture volume
	Depth	mm	Ground Depth
SoilData	Conductivity	m/s	Soil actual Conductivity
	WettingFrontSuction	m/s	Wetting Front Suction
	Porosity	100%	Soil Porosity, not greater than 1

Param

Paramter	Min	Max	Unit	Description
GridN	1	9999	–	NA

OutData

Group	Variable	Unit	Description
Infilt	InfiltrationRat	mm	Infiltration Rate (for some INFITRATION Module)

Return to the Overview of Modules.

3.7 Infiltration

3.7.1 Infiltration.OIER

This Module reference to the Literature: none (**?**).

InData

Group	Variable	Unit	Description
Infilt	InfiltrationRat	mm	Infiltration Rate (for some INFITRATION Module)
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

Paramter	Min	Max	Unit	Description
InfiltrationRateB	0	0	–	–

OutData

Group	Variable	Unit	Description
Infilt	Infiltration	mm	Infiltration

Return to the Overview of Modules.

3.7.2 Infiltration.SER

This Module reference to the Literature: none (**?**).

InData

Param

OutData

Return to the Overview of Modules.

Group	Variable	Unit	Description
Ground	MoistureCapacityMax	mm	Maximal Moisture Capacity
	MoistureCapacity	mm	Moisture Capacity
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Paramter	Min	Max	Unit	Description
SoilMoistureCapacityB	0	0	–	–

Group	Variable	Unit	Description
Infilt	Infiltration	mm	Infiltration

3.8 RUNOFF

3.8.1 RUNOFF.Gr4j

This Module reference to the Literature: Improvement of a parsimonious model for streamflow simulation (Perrin et al., 2003).

InData

Group	Variable	Unit	Description
Ground	MoistureVolume	mm	Moisture volume
Evatrans	AET	mm	Actual evapotranspiration
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

Paramter	Min	Max	Unit	Description
Gr4j_X1	0.1	9.99	mm	NA

OutData

Group	Variable	Unit	Description
Ground	Runoff	mm	Runoff, it will be more wert, when the Runoff is in different form divided
	MoistureVolume	mm	Moisture volume

Return to the Overview of Modules.

3.8.2 RUNOFF.OIER

This Module reference to the Literature: none (**?**).

InData

Param

Group	Variable	Unit	Description
Infilt	InfiltrationRateMax	mm	Maximal Infiltration Rate (for some INFITRATION Module)
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Paramter	Min	Max	Unit	Description
InfiltrationRateB	0	0	–	–

Group	Variable	Unit	Description
Ground	Runoff	mm	Runoff, it will be more wert, when the Runoff is in different form divid
Infilt	Infiltration	mm	Infiltration

OutData

Return to the Overview of Modules.

3.8.3 RUNOFF.SER

This Module reference to the Literature: none (**?**).

InData

Group	Variable	Unit	Description
Ground	MoistureCapacityMax	mm	Maximal Moisture Capacity
	MoistureVolume	mm	Moisture volume
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

Paramter	Min	Max	Unit	Description
SoilMoistureCapacityB	0	0	–	–

OutData

Group	Variable	Unit	Description
Ground	Runoff	mm	Runoff, it will be more wert, when the Runoff is in different form divid
Infilt	Infiltration	mm	Infiltration

Return to the Overview of Modules.

3.8.4 RUNOFF.Vic

This Module reference to the Literature: A new surface runoff parameterization with subgrid-scale soil heterogeneity for land surface models (Liang and Xie, 2001).

Group	Variable	Unit	Description
Ground	MoistureCapacityMax	mm	Maximal Moisture Capacity
	MoistureVolume	mm	Moisture volume
Infilt	InfiltrationRat	mm	Infiltration Rate (for some INFITRATION Module)
Prec	Precipitation	mm	Precipitation, summe of rain and snow

InData

Param

Paramter	Min	Max	Unit	Description
SoilMoistureCapacityB	0	0	–	–
InfiltrationRateB	0	0	–	–

OutData

Group	Variable	Unit	Description
Ground	Runoff	mm	Runoff, it will be more wert, when the Runoff is in different form divided
Infilt	Infiltration	mm	Infiltration

Return to the Overview of Modules.

3.8.5 RUNOFF.VM

This Module reference to the Literature: none (**?**).

InData

Group	Variable	Unit	Description
Ground	MoistureCapacity	mm	Moisture Capacity
	MoistureCapacityMax	mm	Maximal Moisture Capacity
Infilt	InfiltrationRateMax	mm	Maximal Infiltration Rate (for some INFITRATION Module)
Prec	Precipitation	mm	Precipitation, summe of rain and snow

Param

Paramter	Min	Max	Unit	Description
SoilMoistureCapacityB	0	0	–	–
InfiltrationRateB	0	0	–	–

OutData

Return to the Overview of Modules.

Group	Variable	Unit	Description
Ground	Runoff	mm	Runoff, it will be more wert, when the Runoff is in different form divid
Infilt	Infiltration	mm	Infiltration

3.9 GROUNDWATER

3.9.1 GROUNDWATER.Vic

This Module reference to the Literature: none (**?**).

InData

Group	Variable	Unit	Description
Ground	ZoneMoistureVolume	mm	Moisture volume, when the Ground is in more than one
	ZoneDepth	mm	Ground Depth, , when the Ground is in more than one l
	BaseFlow	mm	Base Flow
Infilt	Infiltration	mm	Infiltration
Intercept	Interception	mm	Interception in Canopy
SoilData	Porosity	100%	Soil Porosity, not greater than 1
	SaturatedConductivity	m/s	Soil Saturated Conductivity

Param

Paramter	Min	Max	Unit	Description
GridN	1	9999	–	The nummber of effektive Grids

OutData

Group	Variable	Unit	Description
Ground	Overflow	mm	Overflow, when the caculated water volume greater than Ca
	ZoneMoistureVolume	mm	Moisture volume, when the Ground is in more than one Lay

Return to the Overview of Modules.

3.10 ROUTE

3.10.1 ROUTE.G2RES

This Module reference to the Literature: none (**?**).

InData

Param

OutData

Return to the Overview of Modules.

Group	Variable	Unit	Description
Route	WaterSource	mm	Water Source for Routing, sometimes the same Data with the Runoff
	UHAll	–	All the UH data for all of the Grids for Routr with IUH
	TypeGridID	–	The grids type for Routr with IUH
	TransAll	–	All of the transform Matrix for all of the Grids for Routr with IUH

Paramter	Min	Max	Unit	Description
PeriodN	1	9999	–	The number of Step
GridN	1	9999	–	The nummber of effektive Grids

Group	Variable	Unit	Description
Route	StaFlow	m3/s	Station Flow in the seted grid

3.10.2 ROUTE.Gr4j

This Module reference to the Literature: Improvement of a parsimonious model for streamflow simulation (Perrin et al., 2003).

InData

Group	Variable	Unit	Description
Route	WaterSource	mm	Water Source for Routing, sometimes the same Data with the Runoff
	Store	mm	Store in the Route (for some Module)
	Gr4j_UH1	–	UH form 1 only for Module ROUTE.Gr4j, made by the function
	Gr4j_UH2	–	UH form 1 only for Module ROUTE.Gr4j

Param

Paramter	Min	Max	Unit	Description
Gr4j_X2	0.1	9.99	mm/Step	The catchment water exchange coe icient
Gr4j_X3	0.1	9.99	mm	The one-day maximal capacity of the routing reservoir
Gr4j_X4	1.0	9.99	mm/Step	The HU1 unit hydrograph time base
time_step_i	1.0	9999.00	–	The time Step index

OutData

Group	Variable	Unit	Description
Route	StaFlow	m3/s	Station Flow in the seted grid
	Store	mm	Store in the Route (for some Module)

Return to the Overview of Modules.

Chapter 4

Model

4.1 Classical VIC

Section

4.2 GR4J

Chapter 5

Final Words

We have finished a nice book.

Bibliography

Anderson, E. A. (1973). *National Weather Service river forecast system: snow accumulation and ablation model*, volume 17 of *NOAA technical memorandum NWS HYDRO*.

Arnold, J. G., Srinivasan, R., Muttiah, R. S., and Williams, J. R. (1998). Large area hydrologic modeling and assessment part i: Model development. *Journal of the American Water Resources Association*, 34(1):73–89.

Gash, J. H. C. (1979). An analytical model of rainfall interception by forests. *Quarterly Journal of the Royal Meteorological Society*, 105(443):43–55.

George H. Hargreaves and Zohrab A. Samani (1985). Reference crop evapotranspiration from temperature. *Applied Engineering in Agriculture*, 1(2):96–99.

Liang, X. and Xie, Z. (2001). A new surface runoff parameterization with subgrid-scale soil heterogeneity for land surface models. *Advances in Water Resources*, 24(9-10):1173–1193.

Linacre, E. T. (1977). A simple formula for estimating evaporation rates in various climates, using temperature data alone. *Agricultural Meteorology*, 18(6):409–424.

Lincoln Zotarelli (2014). Step by step calculation of the penman-monteith evapotranspiration (fao-56).

Perrin, C., Michel, C., and Andréassian, V. (2003). Improvement of a parsimonious model for streamflow simulation. *Journal of Hydrology*, 279(1-4):275–289.

Youngs, E. G. and Aggelides, S. (1976). Drainage to a water table analysed by the green-ampt approach. *Journal of Hydrology*, 31(1-2):67–79.