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Supplement of

A hybrid approach to enhance streamflow simulation in data-constrained Himalayan basins: combining the Glacio-hydrological Degree-day Model and recurrent neural networks

Dinesh Joshi et al.

Correspondence to: Dinesh Joshi (joshidinesh0227@gmail.com)

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Parameters Used in the Study

S1 Parameters for GDM model

Table S1 Parameters for Glacio-hydrological Degree-day Model.

Parameters		Data Used for Calibration	
		One year	Three year
Critical temperature		2 ℃	2 ℃
Temperature lapse rate		0.6 ℃ 100 m^{-1}	0.6 ℃ 100 m^{-1}
Precipitation gradient		+20% (‒2680 m)	+20% (‒2680 m)
		+30 % (> 2680 m)	+30 % (> 2680 m)
Recession coefficient		0.90 and 0.008	0.90 and 0.008
Runoff coefficient	Land use type 1	0.5	0.5
	Land use type 2	0.3	0.3
	Land use type 3	0.3	0.3
	Land use type 4	0.95	0.95
Degree day factor	Snow melt (above 500 m)		
	monsoon	8 mm ℃$^{-1}$ day^{-1}	8.5 mm ℃$^{-1}$ day^{-1}
	other months	8 mm ℃$^{-1}$ day^{-1}	7 mm ℃$^{-1}$ day^{-1}
	Snow melt (below 500 m)		
	monsoon	8 mm ℃$^{-1}$ day^{-1}	8.5 mm ℃$^{-1}$ day^{-1}
	other months	8 mm ℃$^{-1}$ day^{-1}	7 mm ℃$^{-1}$ day^{-1}

Ice melt (above 500 m)			
	monsoon	7.5 mm $°C^{-1}$ day^{-1}	10.5 mm $°C^{-1}$ day^{-1}
	other months	7.5 mm $°C^{-1}$ day^{-1}	6 mm $°C^{-1}$ day^{-1}
Ice melt (below 500 m)			
	monsoon	7.5 mm $°C^{-1}$ day^{-1}	10.5 mm $°C^{-1}$ day^{-1}
	Other months	7.5 mm $°C^{-1}$ day^{-1}	6 mm $°C^{-1}$ day^{-1}
	Ice under debris	3 mm $°C^{-1}$ day^{-1}	3 mm $°C^{-1}$ day^{-1}
Rain coefficient			
	monsoon	0.085	0.1
	Other months	0.07	0.05
Snow coefficient			
	monsoon	0.25	0.3
	Other months	0.2	0.15
$\delta_{gw,sh}$		15 days	15 days
$\alpha_{gw,sh}$		0.9	0.9
$\delta_{gw,dp}$		250 days	270 days
$\alpha_{gw,dp}$		1	1
β_{dp}		0.35	0.35
Initial recharge		8 mm	8 mm

S2 Parameters for RNNs

Table S2 Parameters for different RNNs model used in RNNs only approach.

	Simple RNN		LSTM		GRU	
	Data Used for Training		Data Used for Training		Data Used for Training	
Parameters	One year	Three year	One year	Three year	One year	Three year
Number of input units	4	4	4	4	4	4

Number of hidden layers	1	1	1	1	1	1
Number of neurons in each hidden layer	32	32	128	128	128	128
Activation functions in the hidden layer	tanh	tanh	tanh	tanh	tanh	tanh
Activation functions in the output layer	linear	linear	linear	linear	linear	linear
kernel initialize	Glorotuniform	Glorot uniform	Glorot uniform	Glorot uniform	Glorot uniform	Glorot uniform
Dropout rate	-	-	-	-		
Batch size	Whole training data size	Whole training data size	Whole training data size	Whole training data size	Whole training data size	Whole training data size
Optimization algorithm	Adam	Adam	Adam	Adam	Adam	Adam
Sequence length	365	365	365	365	365	365
Input data pre-processing	Normalization	Normalization	Normalization	Normalization	Normalization	Normalization

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loss function	Mean absolute error	Mean absolute error	Mean absolute error	Mean absolute error	Mean absolute error	Mean absolute Error
Number of output units	1	1	1	1	1	1
Number of iterations performed for training	172	437	112	222	82	71
learning rate	0.01	0.01	0.01	0.01	0.01	0.01
learning rate schedule	Exponential decay	Exponential decay	-	-	Exponential decay	Exponential decay
The decay rate for the learning rate schedule	Inverse time-based decay	Inverse time-based decay	-	-	Inverse time-based decay	Inverse time-based decay

S3 Parameters for GDM-RNNs

Table S3 Parameters for different RNNs used in GDM-RNNs hybrid approach

	Simple RNN		LSTM		GRU	
	Data Used for Training		Data Used for Training		Data Used for Training	
Parameters	One year	Three year	One year	Three year	One year	Three year
Number of input units	4	4	4	4	4	4

Number of hidden layers	1	1	1	1	1	1
Number of neurons in each hidden layer	64	128	128	128	128	254
Activation functions in the hidden layer	tanh	tanh	tanh	tanh	tanh	tanh
Activation functions in the output layer	linear	linear	linear	linear	linear	linear
kernel initialize	Glorot uniform	Glorot uniform	Glorot uniform	Glorot uniform	Glorot uniform	Glorot uniform
Dropout rate	0.4	0.2	0.6	0.4	0.5	0.4
Batch size	Whole training data size	Whole training data size	Whole training data size	Whole training data size	Whole training data size	Whole training data size
Optimization algorithm	Adam	Adam	Adam	Adam	Adam	Adam
Sequence length	365	365	365	365	365	365
Input data pre-processing	Normalization	Normalization	Normalization	Normalization	Normalization	Normalization

loss function	Mean absolute error	Mean absolute error	Mean absolute error	Mean absolute error	Mean absolute error	Mean absolute error
Number of output units	1	1	1	1	1	1
Number of iterations performed for training	421	61	157	479	157	269
learning rate	0.01	0.01	0.01	0.01	0.01	0.01
learning rate schedule	-	-	Exponential decay	-	-	-
The decay rate for the learning rate schedule	-	-	Inverse time-based decay	-	-	-