SENSITIVITY ANALYSIS OF THE RUNOFF IN THE LAND SURFACE MODELS FORCED BY THE OUTPUT OF MRI-AGCM 3.2 CLIMATE MODEL

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Introduction

Background

- **Runoff** output from General Circulation Models/Regional Climate Models (GCMs/RCMs) have been widely used to project future change of river discharge.
- However, the simulated flow by **runoff** from GCMs/RCMs is **biased**.
- The **bias** might come from precipitation bias and/or **ROF** bias.
- The ROF is estimated by **Land Surface Model** (**LSM**) embedded in the climate models.
- To improve the **runoff** accuracy, it is necessary to understand the sources of **runoff** bias in the **LSM**.

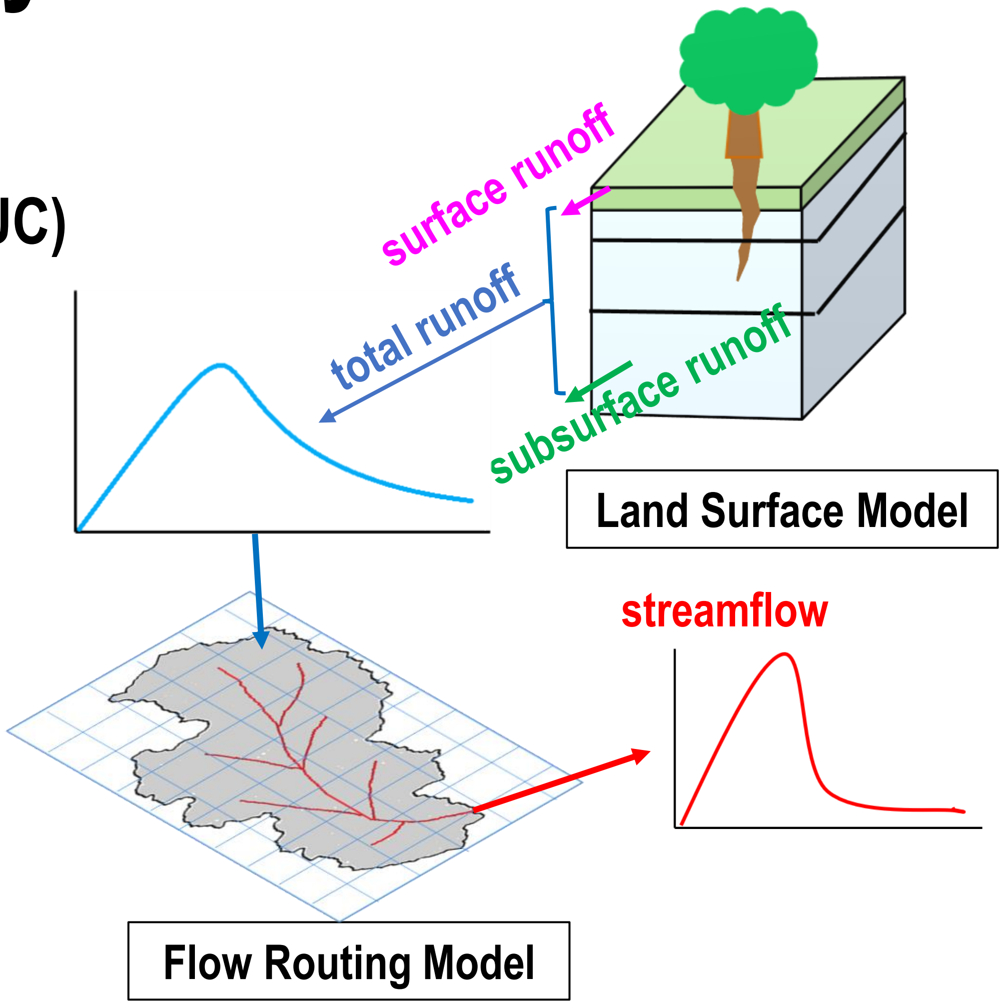
Purpose

To evaluate simulated discharge forced by **runoff** from **LSMs** and investigate the sources of **runoff** uncertainty in the **LSMs**.

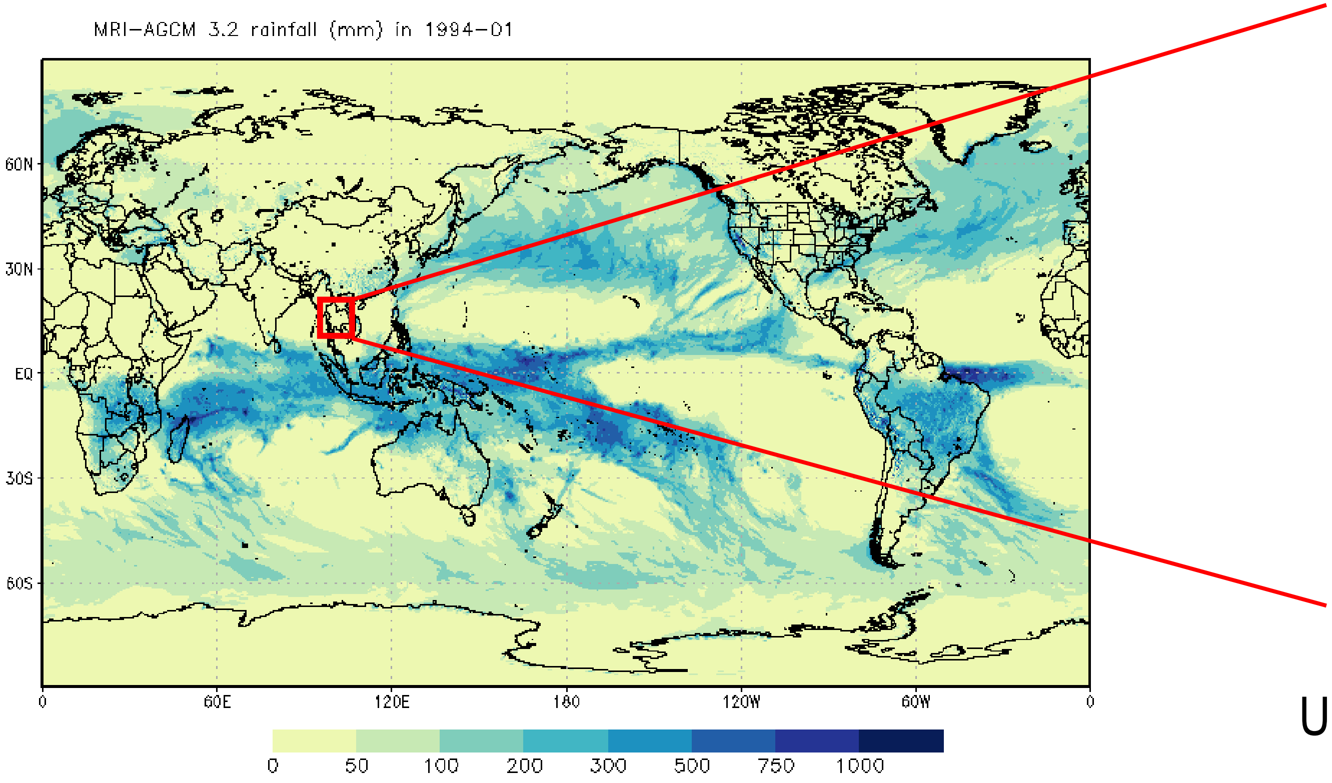
Methodology

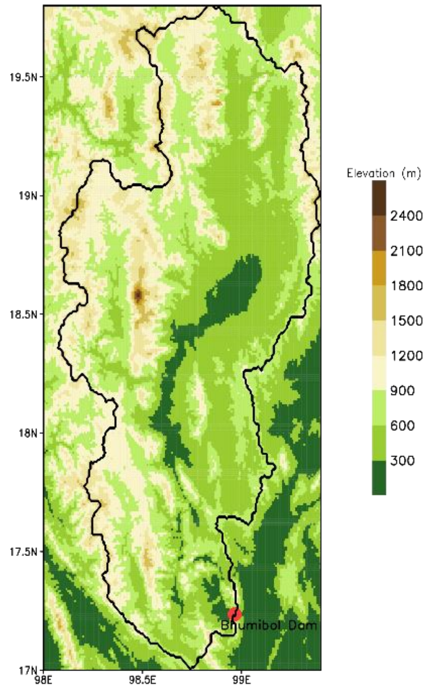
- In this study, ROF output from two LSMs is analyzed.
    - **Simple Biosphere including Urban Canopy (SiBUC)** (Tanaka, 2005).
    - **Meteorological Research Institute - Simple Biosphere (MRI-SiB)** (Hirai *et al.*, 2007)
- Both LSMs have been developed based on Simple Biosphere (SiB) (Sellers *et al.*, 1986).
- Total ROF from both LSMs are utilized as input for 1K-FRM to simulate the river discharge.

Total ROF = surface ROF (Qs) + subsurface ROF (Qsb)



Forcing data and study area



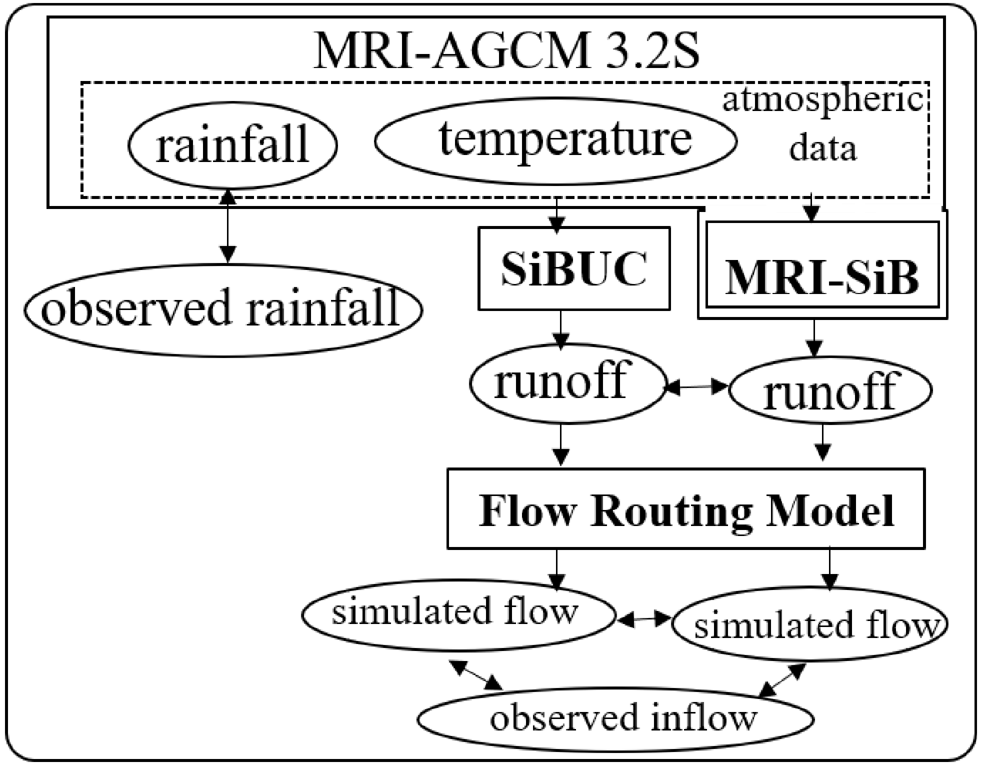


Upper part of Ping River Basin
(26,100 km^2)

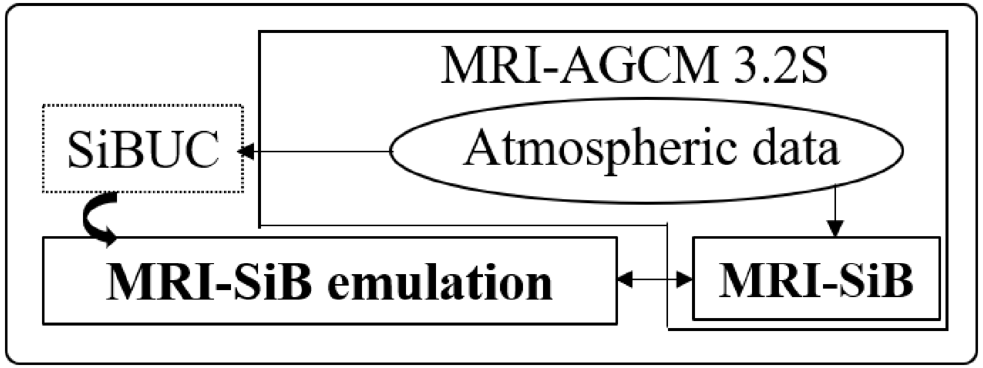
MRI-AGCM 3.2S atmospheric data was used as forcing for both LSMs.
Study area is upper part of Ping River Basin (tributaries of Chao Phraya River Basin) in Thailand.

Simulation period: 1979-2003 , spin-up period: 1979-1983, analysis period: **1984-2003**

Framework of this study



1. Evaluation of discharge simulated by LSMs.



2. Investigation of runoff generation schemes in LSMs.

1. Evaluation of discharge simulated by LSMs.

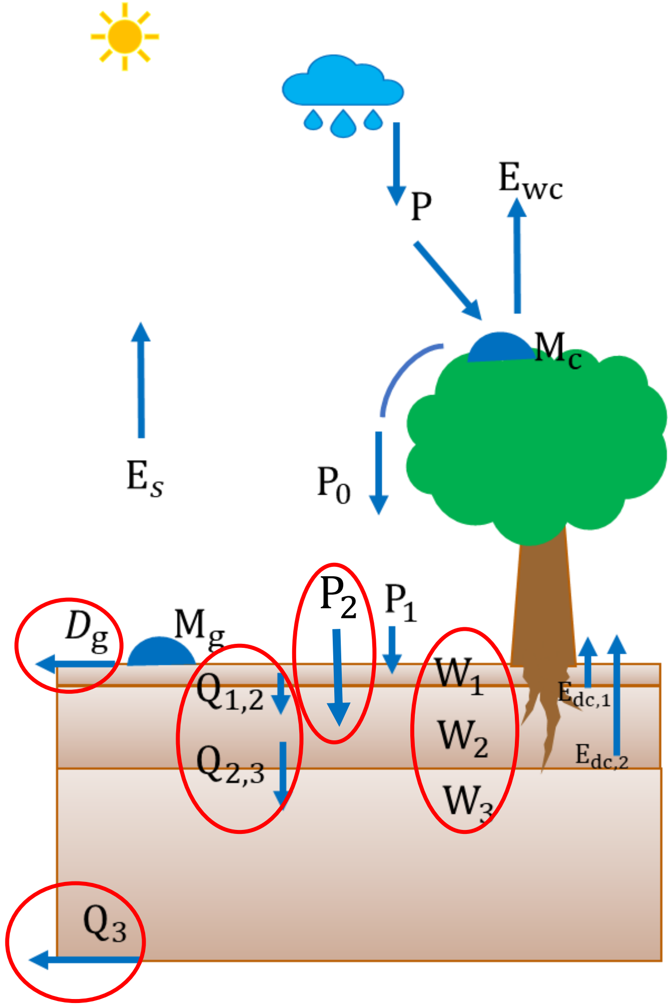
- Comparison of simulated rainfall with observed rainfall
- Analysis of runoff characteristics by LSMs
- Comparison of streamflow estimated by LSMs with observed river discharge.

2. Investigation of runoff generation schemes in LSMs.

- Sensitivity analysis of the impacts of model settings on runoff characteristics.

Different settings between SiBUC and MRI-SiB

Settings	SiBUC	MRI-SiB
(a) Soil parameters		
z_i(m)	~ 12.5	~ 3.5
K_s (m s[-1])	8.35×10^{-6}	1.76×10^{-4}
φ_s(m)	-0.63	-0.086
(b) Model structures		
Direct infiltration into deeper soil layer " P_2"	-	incorporated
Soil-water flow equation	$Q_{i,i+1} = K\left[\frac{\partial\varphi}{\partial z} + 1\right]$	$Q_{i,i+1} = K\left[\frac{\partial\varphi}{\partial z}\right]$
Subsurface ROF estimation	$Q_3 = \sin \emptyset_s K_s W_3^{2B+3}$	$Q_3 = sin\theta_s K_s W_3^{2B+3}\left[1 + \frac{\varphi_2 - \varphi_3}{z_3}\right]$
(c) Numerical scheme for updating soil moisture	explicit-midpoint method	semi-implicit method

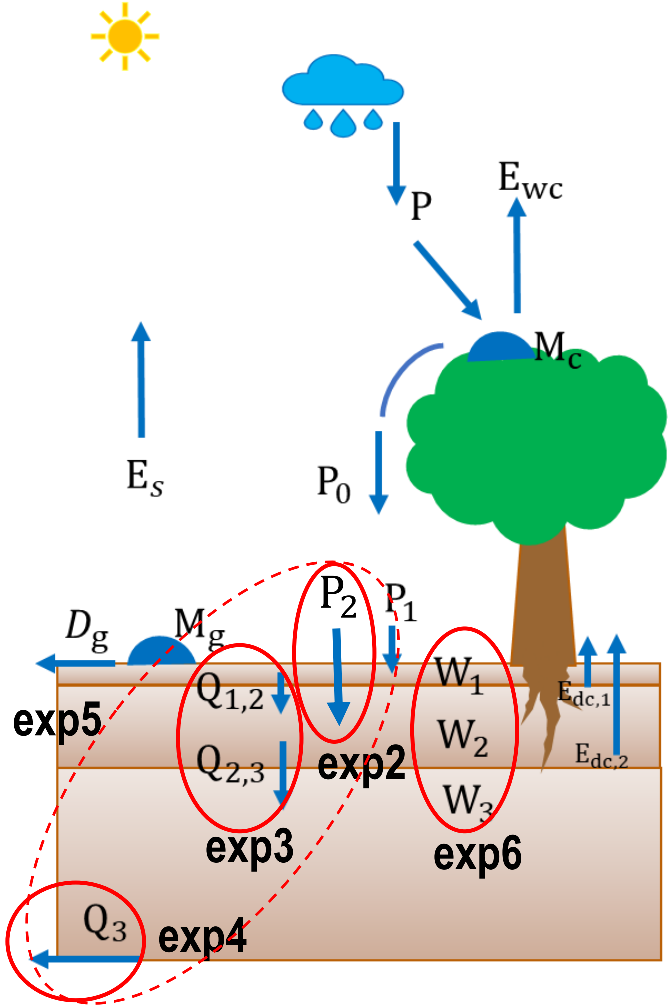


Variables that are treated differently in both LSMs

$Q_{i,i+1}$: flow between soil layer, φ_i: matric potential, W_i: soil moisture, K_i: hydraulic conductivity, z_i: soil depth

Experimental designs

Settings	Experiment					
	1	2	3	4	5	6
Control (SiBUC) original SiBUC settings	-	-	-	-	-	-
Soil parameters SiBUC→ MRI-SiB	✓	✓	✓	✓	✓	✓
Incorporating P_2	-	✓	-	-	✓	✓
Soil-water flow eq. $Q_{i,i+1} = K\left[\frac{\partial\varphi}{\partial z}+1\right] \rightarrow Q_{i,i+1} = K\left[\frac{\partial\varphi}{\partial z}\right]$	-	-	✓	-	✓	✓
Subsurface runoff eq. $Q_3 = \sin\emptyset_s K_s W_3^{2B+3} \rightarrow$ $Q_3 = sin\theta_s K_s W_3^{2B+3}\left[1+\frac{\varphi_2-\varphi_3}{D_3}\right]$	-	-	-	✓	✓	✓
Numerical scheme Explicit-midpoint → semi implicit	-	-	-	-	-	✓



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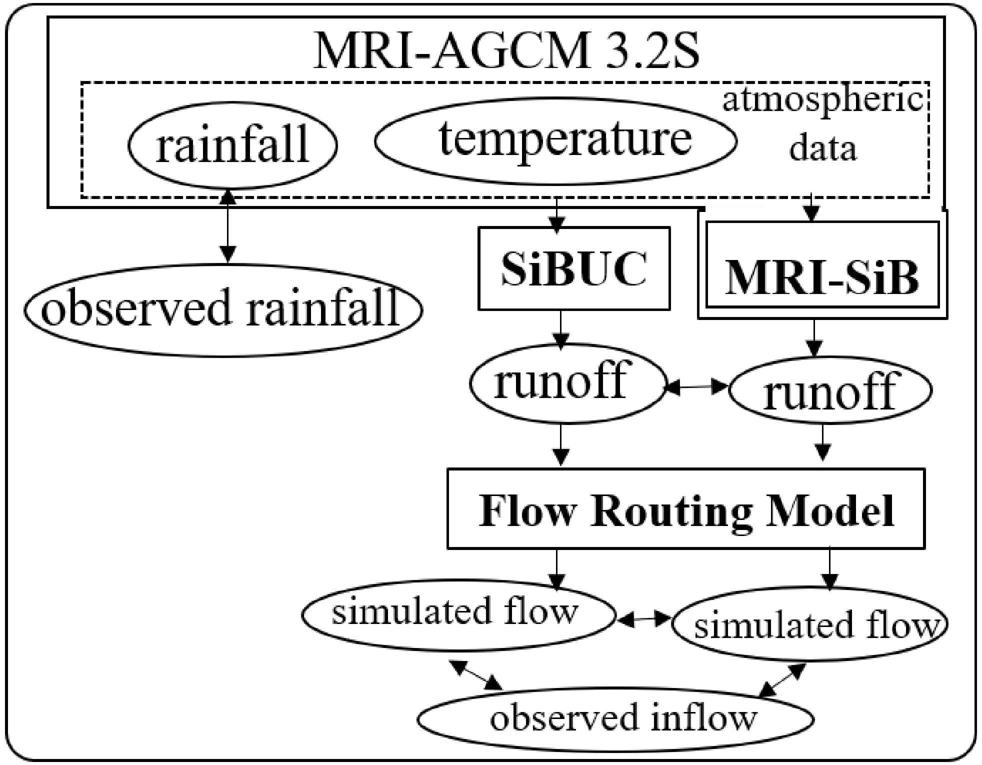

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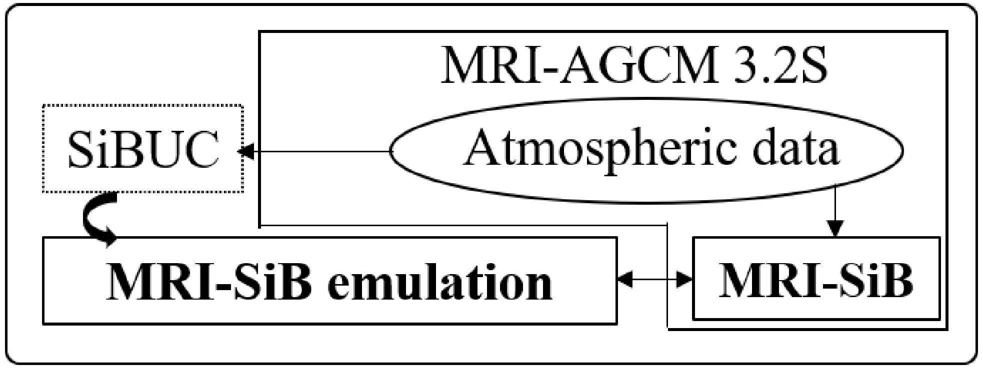

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   - Comparison of simulated rainfall with observed rainfall
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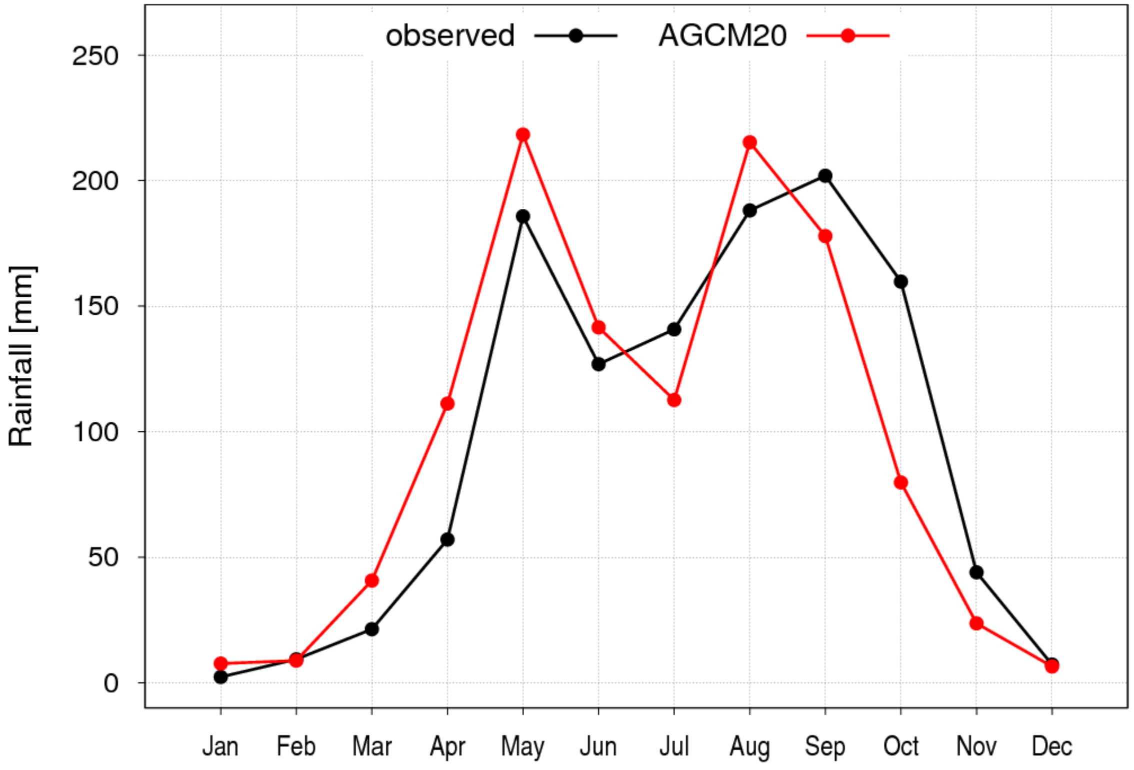
Evaluation of climatological mean of monthly rainfall

- Distinct distribution of observed rainfall during wet and dry seasons could be well captured by simulated rainfall by GCM.
- The mean annual rainfall by GCM was close to the observation.



COMPARISON OF WATER BUDGET

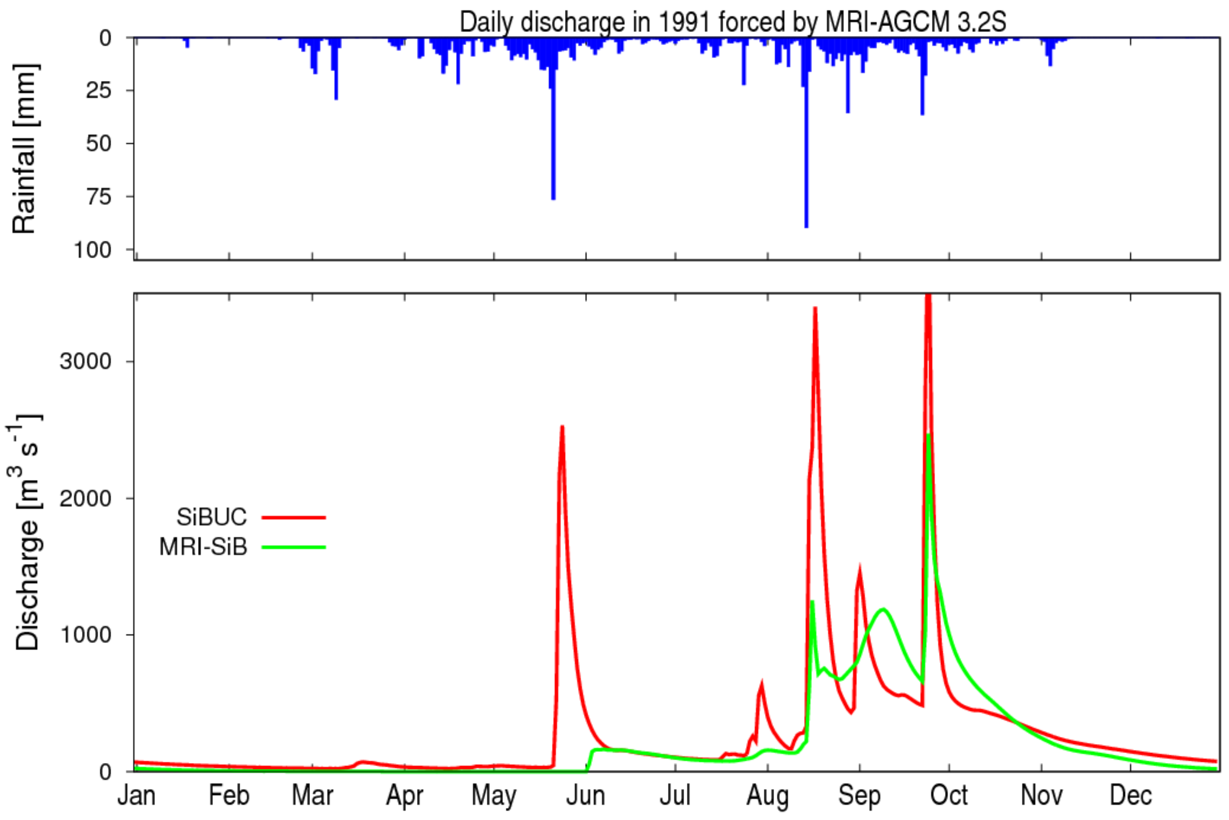
Water budget components (mm year^{-1})	LSMs	
	SiBUC	MRI-SiB
Evapotranspiration (ET)	976	999
Runoff (ROF)	194	146
Surface runoff (Qs)	**58**	**3**
Subsurface runoff (Qsb)	**136**	**143**
Change of soil moisture (delSM)	-17	1

- **MRI-SiB** tends to estimate higher **evapotranspiration** and lower **runoff** than **SiBUC**.
- **SiBUC** tends to generate higher **surface runoff** than **MRI-SiB**.
- **Subsurface runoff** is the dominant **runoff** components in **MRI-SiB**.

Characteristics of daily discharge using runoff generated by LSMs

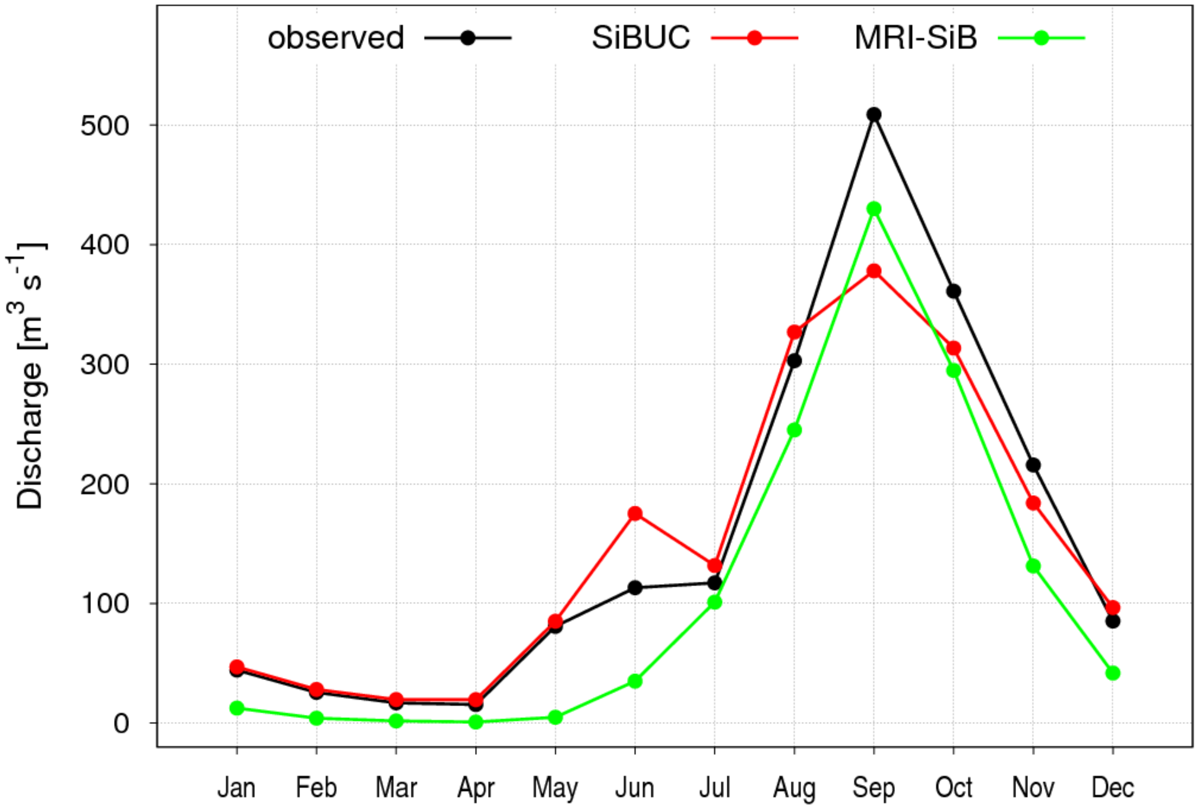
- Time series of streamflow by **SiBUC** shows similar response to the rainfall.

- Estimated discharge by **MRI-SiB** is mainly affected by catchment wetness, particularly in the early rainy season.

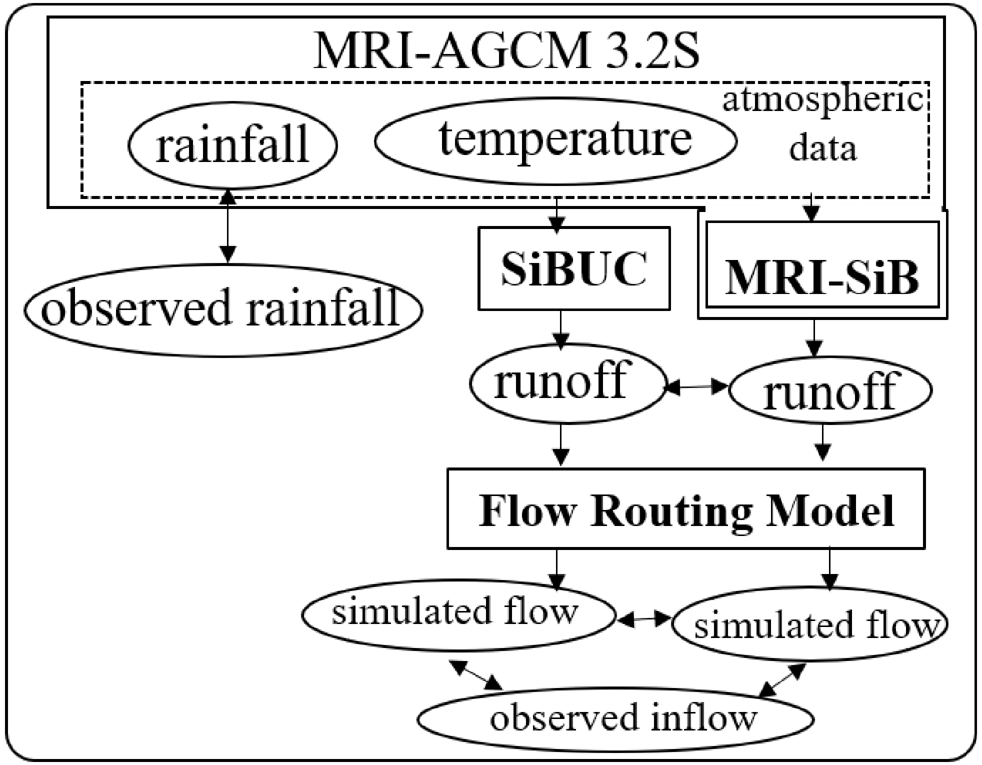


Evaluation of streamflow simulated by runoff from LSMs

- Both LSMs could reproduce seasonal changes of observed inflow in this basin.
- SiBUC tends to have a better reproducibility of observed inflow.
- Peak discharge by MRI-SiB is closer to the peak observation.



20-years-mean monthly discharge.



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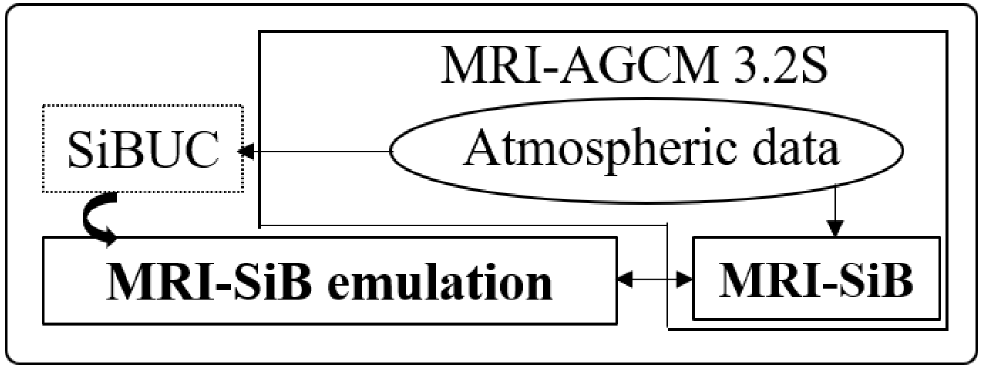

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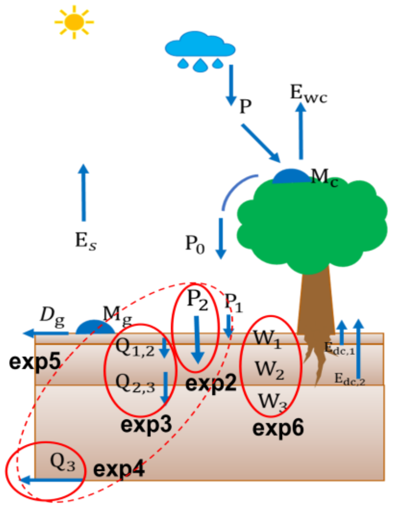
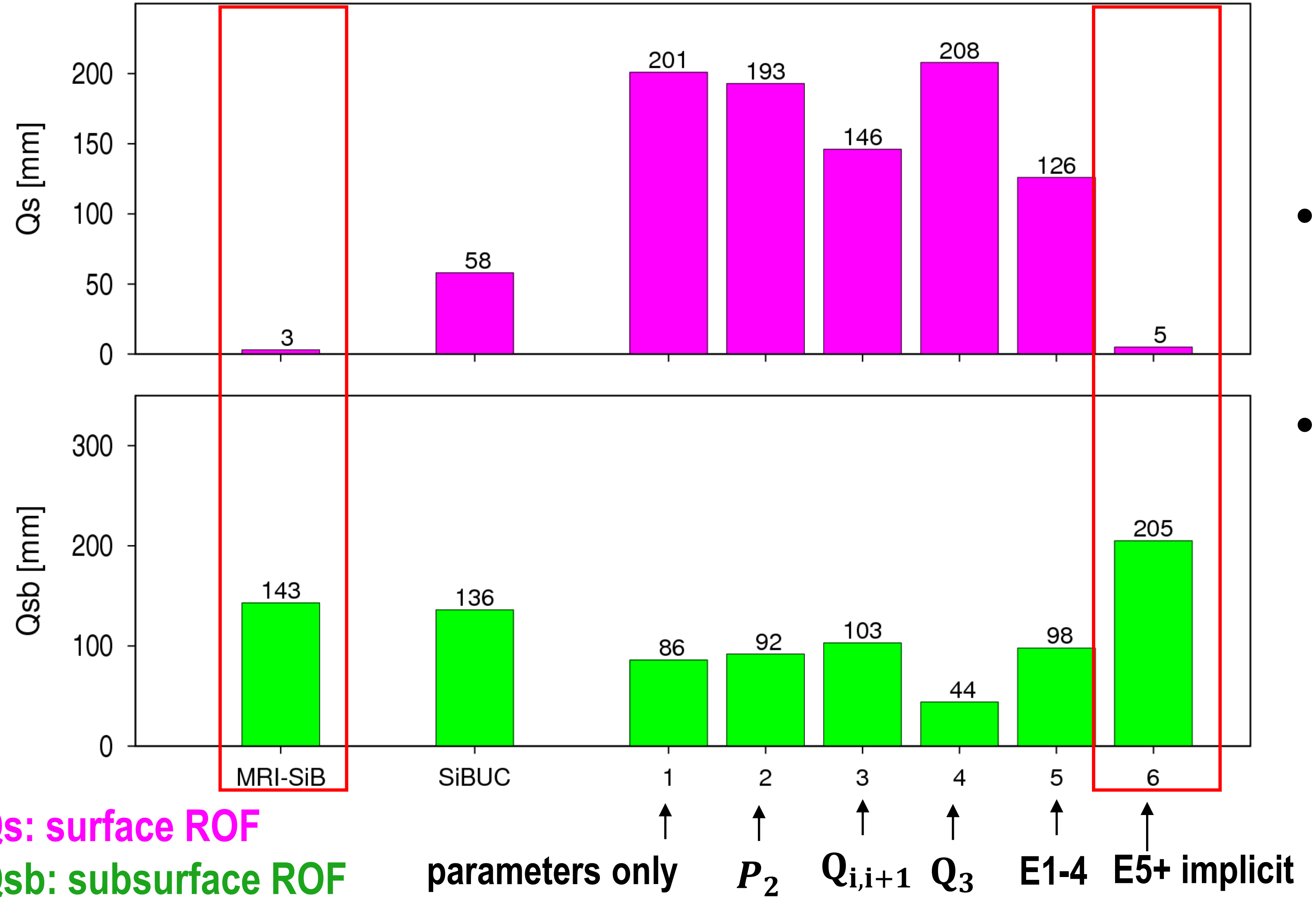
INVESTIGATION OF RUNOFF GENERATION SCHEMES in LSMs



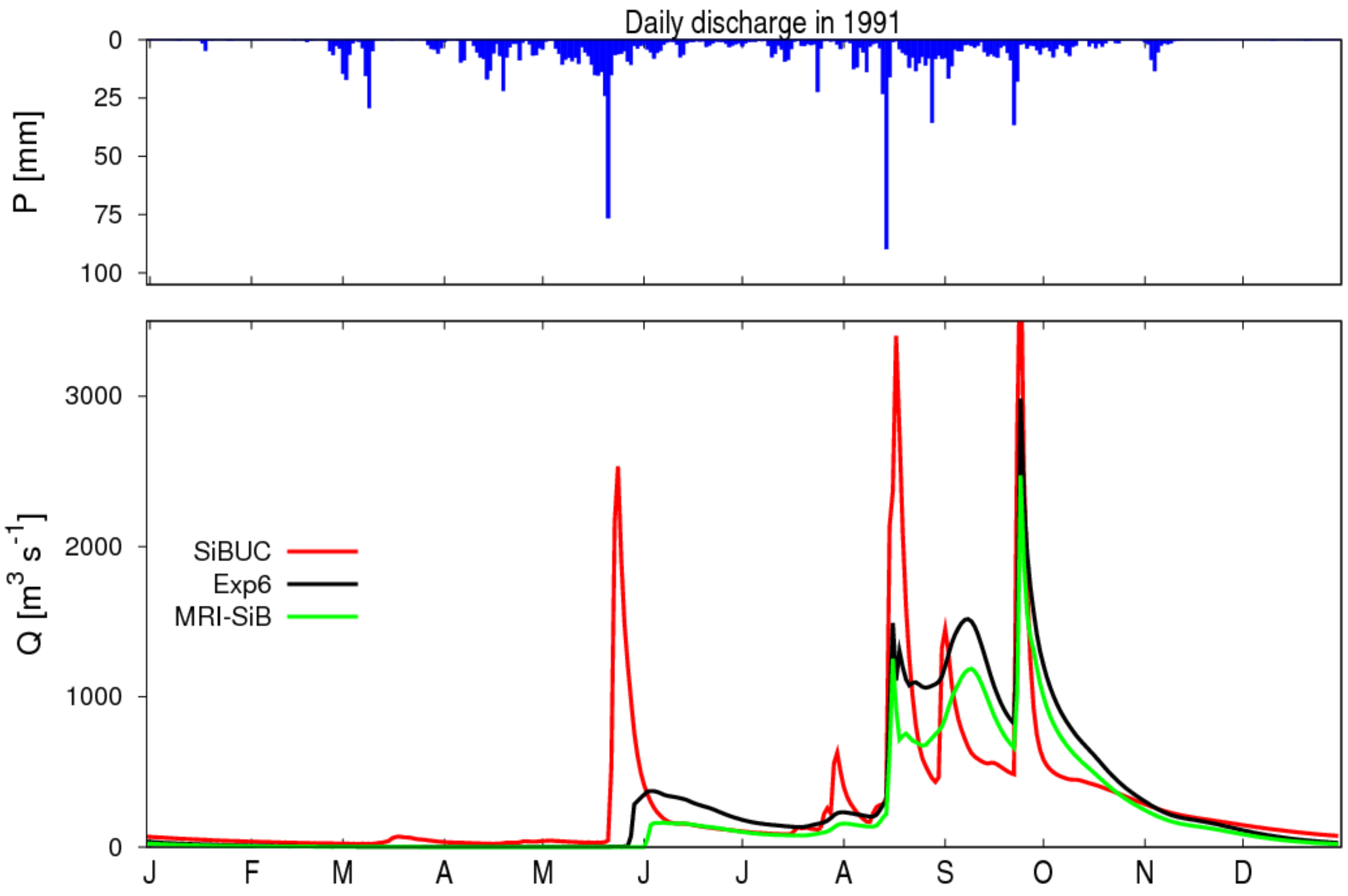


Qs: surface ROF

Qsb: subsurface ROF

- Each setting has shown some impacts on runoff characteristics.
- By adopting **MRI-SiB parameters**, **model structures**, and **numerical scheme for updating soil moisture** in SiBUC, MRI-SiB's runoff characteristics could be reproduced by SiBUC.

Characteristics of the estimated daily discharge



Simulated discharge by each LSM using MRI-AGCM 3.2 atmospheric data

- The simulated discharge by experiment 6, by adopting **MRI-SiB parameters**, **model structures**, and **numerical scheme for updating soil moisture** in SiBUC, shows a similar temporal pattern of MRI-SiB.

- The analysis from this study has shown some insights to identify potential sources of runoff bias in the land surface models.

Conclusions and future work

- This study aimed to evaluate simulated **streamflow** forced by **runoff** from **LSMs** and investigate the **sources of runoff** uncertainty in the LSMs.
- From runoff analysis, both LSM showed different **runoff characteristics**: higher **surface runoff** in **SiBUC** and dominant **subsurface runoff** component in **MRI-SiB**.
- The different runoff estimation by each LSM has impacts on the simulated streamflow.
- To determine the reasons for such differences, runoff generation schemes in both LSMs were analyzed in detail.
- This study identified different settings in SiBUC and MRI-SiB that mainly affected the runoff generation: **soil parameters**, **model structures**, and **time integration methods.**
- The analysis from this study has shown some insights to identify potential sources of runoff uncertainty in the land surface models.
- Future work should evaluate and improve the performance of each LSM for reproducing the observed discharge.