

1.Introduction

In recent years, deep learning has been applied to various issues in natural science, including hydrology. These application results show its high applicability. There are some studies that performed rainfall-runoff modeling by means of a deep learning method, LSTM (Long Short-Term Memory). LSTM is a kind of RNN (Recurrent Neural Networks) that is suitable for modeling time series data with long-term dependence. These studies showed the capability of LSTM for rainfall-runoff modeling. However, there are few studies that investigate the effects of input variables on estimation accuracy. Therefore, this study, investigated the effects of the selection of input variables on the accuracy of a rainfall-runoff model by means of LSTM.

2. Study Area

The Ishikari River originates from Mt.Ishikari whose altitude is 1,967 meters above sea level. This channel length is 268km, which is the third-largest in Japan. This basin is 14,330km², which is the second-largest in Japan. This basin is located at E141° 20'45" N43° 14'14" alt (Figure 1). This basin which is a snow-accumulated area accumulates a lot of snow in winter. The accumulated-snow period is from November to March, and the snow-melting period is from April to May. The flow discharge in this basin increases significantly compared to other periods.

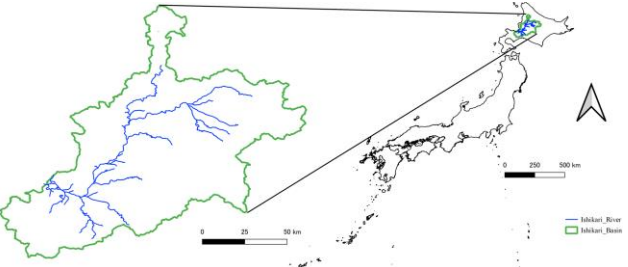


Figure 1. Ishikari basin in Japan

3.Data set & Methodology

This study uses observed the following datas.

●Input data

Input datas is this Table1:

Table1. Input data	
Abbreviations	Official names
p	Precipitation
t	2 metre temperature
lr	Mean surface downward long-wave radiation flux
Sr	Mean surface downward short-wave radiation flux
e	Evaporation
msl	Mean sea level pressure

Table2. Input data	
Case number	Input data
Case1	p,t,e,lr,sr,msl
Case2	p,t,lr,sr
Case3	p,t,lr,sr,e
Case4	p,t,lr,sr,msl
Case5	p,t,e
Case6	p,t,msl
Case7	p,t,e,msl
Case8	p,t

- This study utilizes a deep learning framework for python, Torch.
- The dataset is divided into three periods: training(1997-2009), validation(2010-2012),and test periods(2013-2015).

• the equations for LSTM cells are:

$$i(t) = \sigma(W_{ii}x(t) + b_{ii} + W_{hi}h(t-1) + b_{hi}) \quad (1)$$

$$o(t) = \sigma(W_{io}x(t) + b_{io} + W_{ho}h(t-1) + b_{ho}) \quad (2)$$

$$f(t) = \sigma(W_{if}x(t) + b_{if} + W_{hf}h(t-1) + b_{hf}) \quad (3)$$

$$g(t) = \tanh(W_{ig}x(t) + b_{ig} + W_{hg}h(t-1) + b_{hg}) \quad (4)$$

$$c(t) = f(t) \cdot c(t-1) + i(t) \cdot g(t) \quad (5)$$

$$h(t) = o(t) \cdot \tanh(c(t)) \quad (6)$$

i(t) : Input gate at time t
o(t) :Output gate at time t
f(t) :Forget gate at time t
g(t) :Cell gate at time t
h(t) :Hidden state at time t
c(t) :Cell state at time t

x(t) is the input vector at time $W_i, W_o, W_f, W_{ig}, W_{hg}$ are weights, and $b_{ii}, b_{io}, b_{if}, b_{ig}, b_{hi}, b_{ho}, b_{hf}, b_{hg}$ are bias weights.

4. Results & Discussion

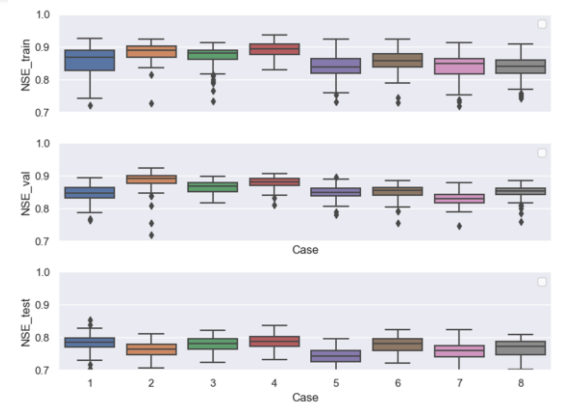


Figure2. NSE of each cases

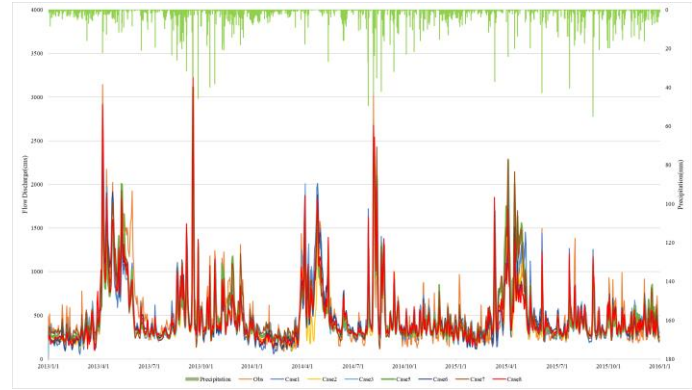


Figure3. Hydrograph of each cases

5. Conclusion

The use of meteorological variables in addition to precipitation and air temperature as input improved the model accuracy. In some cases, however, the model accuracy was worsened by using more variables as input. The results indicate the importance to select adequate variables as input for rainfall-runoff modeling by LSTM.