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Predication of Stable Isotopes (^{18}O and ^{2}H) in Precipitation of Bangkok Metropolitan Using Artificial Neural Network †

Mojtaba Heydarizad and Nathsuda Pumijumnong *

Faculty of Environment and Resource Studies, Mahidol University, Nakhon Pathom 73170, Thailand; mojtaba.hey@mahidol.ac.th

* Correspondence: nathsuda.pum@mahidol.ac.th; Tel.: +66-24415000-2311

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Abstract: The role of local (wind speed, potential evaporation, vapor pressure, air temperature, and precipitation amount) and regional parameters (teleconnection indices such as IOD, BEST, NAO, SOI, and QBO) on stable isotopes content in Bangkok precipitation has been investigated. Firstly, simple artificial neural network (ANN) and Deep Learning Neural Network (DNN) have been used to predict stable isotopes content in precipitation. Furthermore, studying the fractional importance of various parameters on stable isotopes content of precipitation demonstrates that among the local parameters (precipitation amount and potential evaporation) and among the regional parameters (BEST teleconnection index) have the dominant role in controlling the stable isotopes content of precipitation.

Keywords: precipitation; Bangkok; stable isotopes; prediction; artificial neural network

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1. Introduction

Thailand is a country in southeast Asia located in the tropical climate zone between the Pacific and the Indian oceans. According to the Köppen climate classification, Thailand is mainly covered by two dominant tropical Savanna (Aw) and tropical monsoon (Am) climate zones [1]. Thailand climate is mainly controlled by the seasonal variations of moisture transfer from the Indian and the Pacific oceans. The northeast monsoon from the Pacific Ocean and the southwest monsoon from the Indian Ocean control this country climate [2] (Figure 1). The northeast monsoon (NE) affects Thailand from Mid-October until Mid-February and the role of the Pacific Ocean is dominant during this period. However, southwest monsoon (SW) influences Thailand from Mid-May to Mid-October and precipitation moisture originates from the Indian Ocean [2].

The spatial and temporal variations in precipitation moisture sources normally influences the stable isotopes content of precipitation. Studying and monitoring the stable isotopes (^{18}O and ^{2}H) in precipitation and other elements of hydrological cycle such as groundwater or surface water resources can give valuable information in many fields of hydrological, hydrogeological and climatological sciences [3]. Stable isotopes sampling in precipitation across Thailand commenced in 1968 when the first Global Network of Isotopes in Precipitation (GNIP) station has been stablished in Bangkok metropolitan. Bangkok is the capital and most populated metropolitan of Thailand in the Chao Phraya delta in the central part of this country.

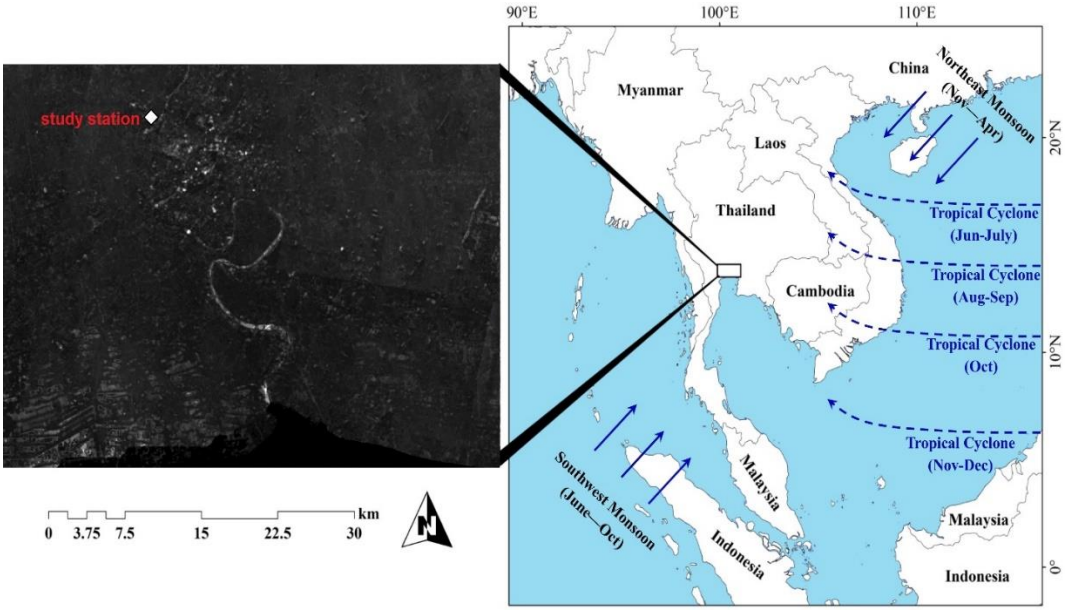

Figure 1. The main air masses influence Thailand and the direction of SW and NE monsoons as well as the study area location (After Laonamsai et al., [4]).

The aim of this investigation is to study comprehensively the role and fractional importance of various regional (teleconnection indices) and local parameters on the stable isotopes content of precipitation in Bangkok metropolitan. In addition, the stable isotopes content in Bangkok precipitation has been simulated using artificial neural network techniques. Bangkok GNIP station is one of the major stations in the world with over 47 years monthly stable isotope data sets which makes it suitable for the current study.

2. Materials and Methods

In the following survey, the stable isotopes (^{18}O and ^{2}H) in precipitation samples have been studied for 47 years between 1968 till 2015 in Bangkok station. The stable isotopes are all presented in delta notation δ relative to VSMOW standard and presented in ‰ unites with the analytical uncertainties of 0.1 ‰ and 1 ‰ for ^{18}O and ^{2}H isotopes, respectively. The local parameters including wind speed, and potential evaporation were downloaded from the NOAA website [5]. However other parameters such as precipitation amount, vapor pressure and air temperature were also presented in the same file as stable isotopes in GNIP data set for Bangkok. In addition to the local factors, the role of regional parameters (teleconnection indices) on the stable isotopes content of Bangkok precipitation have been studied. Southern Oscillation Index (SOI), Bivariate ENSO (BEST), The Quasi-Biennial Oscillation (QBO), the North Atlantic Oscillation (NAO), the Indian Ocean Dipole (IOD), and the El Nino-Southern Oscillation (ENSO) are the main teleconnection indices influence climate in southern part of Asia including Thailand [6,7]. These teleconnection indices data are available for freeat NOAA website [5,8].

To simulate the stable isotopes content of precipitation as well as determining the fractional importance of various parameters in controlling the stable isotopes content of precipitation, artificial neural network techniques have been used. The ability and the accuracy of simple artificial neural network (ANN) as well as Deep Learning Neural Network (DNN) to forecasts stable isotopes content in Bangkok precipitation has been investigated. The ANN model unlike conventional statistical techniques are very applicable for the problems which contains complicated nonlinear interactions which make it reliable method to forecast stable isotopes content in precipitation [9–12]. To develop predictive models, local (wind speed, potential evaporation, vapor pressure, air temperature, and precipitation amount) as well as regional parameters (teleconnection indices such as IOD,

BEST, NAO, SOI, and QBO) were used to predict stable isotopes content in Bangkok precipitation. In addition, to involve the role of moisture sources in the models, the stable isotope data set has been classified to three groups based on the month of precipitation sampling to SW monsoon (group1), NE monsoon (group2) and transition (group3). Finally, the role and fractional importance of each independent local and regional parameter in the final models has been estimated by the DNN and ANN models.

3. Results and Discussion

Stable isotopes signature in precipitation of Bangkok has been studied and the stable isotopes content have been simulated by simple ANN and more complicated DNN models. To simulate the stable isotopes in precipitation, the local and regional parameters influencing the stable isotopes content in precipitation have been entered to the DNN and ANN models as input data. Comparing the simulated and real isotope data (Figure 2) shows that both DNN and ANN models can simulate the stable isotopes content with acceptable accuracy. To quantify the accuracy of the simulated stable isotopes content, the correlation between real and simulated stable isotopes have been investigated and the coefficient of determination (R^2) have been calculated for both models (Figure 3). The results show that the R^2 values for both isotopes (^{18}O and ^{2}H) and for both models are approximately the same ranging from 62% to 66%. This is not very high R^2 values but acceptable accuracy for the developed models. To achieve more accurate models, the role of other parameters including cloud top pressure (CTP), cloud top temperature (CTT), and the role of inland/continental moisture sources should also be considered in the models. The CTP and CTT data sets are not available for the whole Bangkok stable isotopes data sets (just for 15 years from 2000 till 2015). However, no comprehensive investigations have been done on the role of inland/continental moisture sources on stable isotopes content of precipitation in Thailand yet. Therefore, these parameters cannot involve in the developed models in this study.

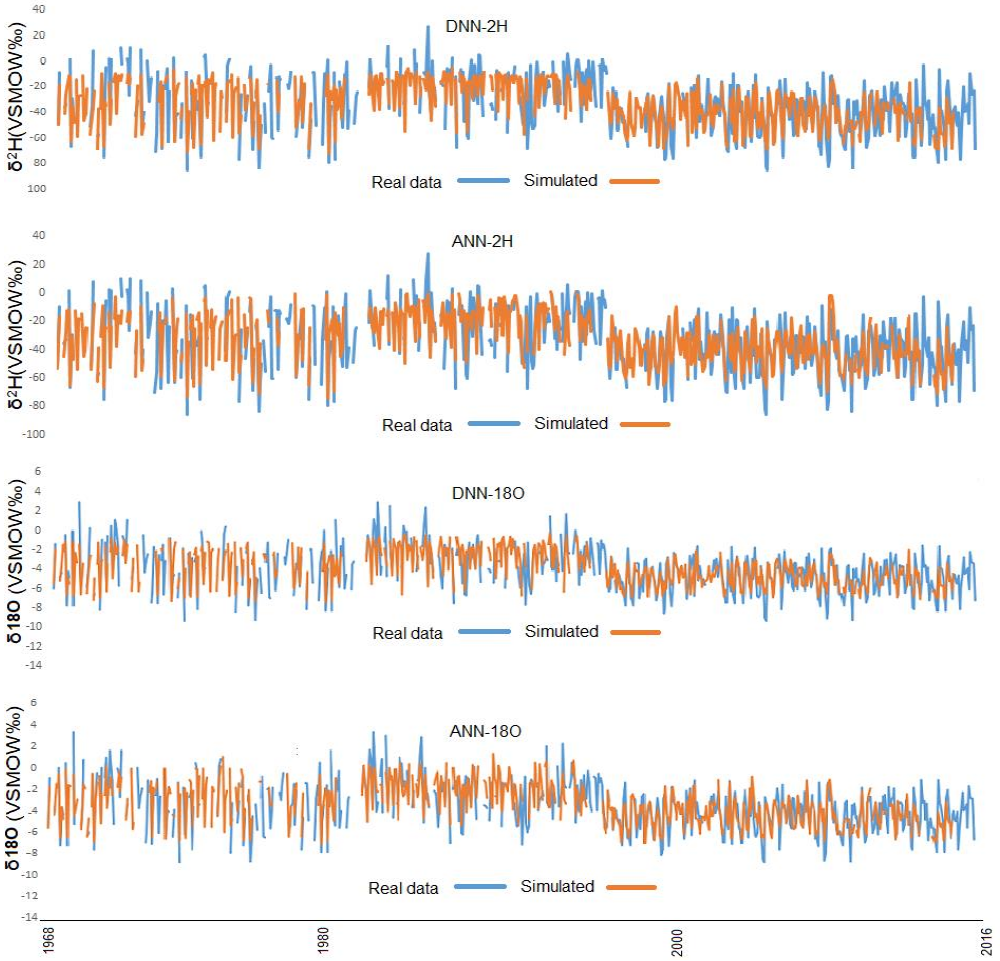

Figure 2. The comparison between the real and simulated stable isotopes data using DNN and ANN models in Bangkok precipitation.

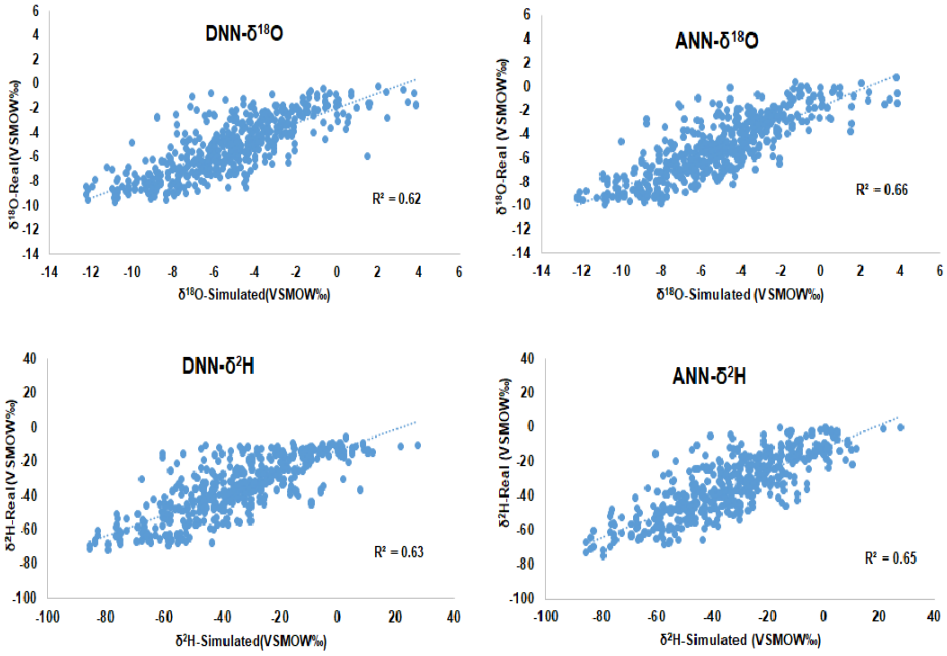

Figure 3. The regression correlation between the real and simulated stable isotopes data in Bangkok precipitation and R^2 score values.

In addition to the simulation of stable isotopes in precipitation, the fractional importance of each local and regional parameters influencing stable isotopes in precipitation have also been calculated by both DNN and ANN models (Table 1). According to the outputs of the models, potential evaporation and precipitation amount are the main local parameters influencing the stable isotopes in precipitation. However, BEST teleconnection index is the main regional parameter influences the stable isotopes content of precipitation in Bangkok. Other local and regional parameters are also influencing the stable isotopes content of precipitation, but they have weak role compare to the dominant mentioned factors.

Table 1. Calculated fractional importance of the main local and regional parameters influencing $\delta^{18}O$ and $\delta^{2}H$ in Bangkok precipitation.

Parameter	ANN- $\delta^{18}O$	DNN- $\delta^{18}O$	ANN- $\delta^{2}H$	DNN- $\delta^{2}H$
IOD	0.04	0.06	0.05	0.07
NAO	0.07	0.06	0.06	0.03
QBO	0.05	0.05	0.03	0.03
SOI	0.07	0.04	0.07	0.05
BEST	**0.15**	**0.12**	**0.16**	**0.15**
Wind speed	0.05	0.06	0.05	0.04
Evaporation	**0.23**	**0.26**	**0.25**	**0.27**
Vapor pressure	0.07	0.08	0.08	0.09
Air temperature	0.10	0.07	0.06	0.05
Precipitation amount	**0.17**	**0.15**	**0.16**	**0.19**
Season	0.03	0.05	0.04	0.03

4. Conclusions

The results of this study reveals that both DNN and ANN models provide approximately the same level of accuracy to forecast stable isotopes content in Bangkok precipitation. Furthermore, studying the role of various local and regional parameters also shows that precipitation amount and potential evaporation (among the local parameters) and BEST index (among the regional parameters) are the dominant factors controlling the stable isotopes content of precipitation in Bangkok.

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Conflicts of Interest: The authors declare no conflict of interest.

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