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DEVELOPMENT OF SUMATERA EARLY WARNING CONVECTIVE SYSTEM (SANCIS) FOR THUNDERSTORM PREDICTION MODEL

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Abstract

Since the activity of thunderstorm over Sumatera area – Indonesia increased during intermonsoon season in September, October, and November (SON) month, the thunderstorm as a natural disaster is influenced by human activity. During the thunderstorm status increased may change economy factors in this state due to natural hazard damage. Therefore, the development of Sumatera eArly warNing of ConvectIve System (SANCIS) for Thunderstorm Prediction System is necessary to avoid the natural hazard victims and helping meteorologist to predict thunderstorm event. To support the SANCIS development, the researchers designed the thunderstorm model based on Adaptive Neuro Fuzzy Inference System (ANFIS). This system is equipped database meteorology and satellite imaging to update information and status thunderstorm event. In addition, to create the ANFIS model use two variables such as relative humidity (H) and PWV from radiosonde (RSPWV) from Weather Underground (WU) website and University of Wyoming (UW), respectively. Furthermore, the thunderstorm status prediction was updated in the SANCIS website. The two information per-day of status thunderstorm prediction were covered thunderstorm activity in this area. Finally, the system was designed to monitor and to give information about thunderstorm status during thunderstorm events.

Keywords: Early Warning System, SANCIS, Thunderstorm, and Lampung

A. Introduction

Electrical storm, heavy rain, and strong winds a phenomenon is categorized Thunderstorm natural hazard. Here, heavy rain and electrical storm have a risk to attempt human activity. Many researchers propose an early warning system to evaluate the risk of thunderstorm activity. For example, More than 75% space shuttle countdowns due to thunderstorm activity between 1981 and 1994 (Hazen et al, 1995). Based on incident over 1981 and 1994, Researcher continues to study to find the best method for monitoring thunderstorm activity with high acquisition and accuracy. The numerical methods (Spiridonov & Curic, 2003) and sensor measurements (Kuk et al, 2012) were suggested to predict characteristics thunderstorms activity.

In order to predict thunderstorms activity with limited budget, an Artificial Intelligent model has suggested obtaining thunderstorm activity. Here, ANN with Levenberg Marquardt and Delta–Bar–Delta logarithms were suggested to predict thunderstorm over Kolkata, India (Litta et al, 2013) However, several researchers mentioned that ANN method have limitation to predict thunderstorm activity (Suykens, 2001). Thus, to improve ANN limitation to predict thunderstorm activity in Sumatera, Indonesia, use Adaptive Neuro-Fuzzy Inference System (ANFIS) to implemented on Sumatera eArly warNing of ConvectIve System (SANCIS).

Since, ANFIS is proposed to predict Thunderstorm activity in early warning system, the researchers use Weather Research and Forecasting EMS (WRF EMS) software to validate thunderstorm prediction model. Here, the WRF EMS software based on numerical weather prediction (NWP) and designed to serve both of atmospheric research and operational forecast (Rajasekaran and Pai, 2003) Therefore, this work aimed to comparing acquisition and accuracy of SANCIS system with WRF software by using statistical method. The simulation result of SANCIS system and WRF software is used to obtain acquisition and accuracy value from selected input such as Relative Humidity (*H*) and Radiosonde Precipitable Water Vapor (*RSPWV*) to obtain thunderstorm model from both simulations.

B. Methodology

1. Research Design

Since, the thunderstorm activity over Sumatera area has been increased during the December, January, and February (DJF) months (Suparta et al, 2015) researchers use Relative Humidity (*H*) from weather underground website (https://www.wunderground.com) while Radiosonde Precipitable Water Vapor (*RSPWV*) data derived from University of Wyoming (http://weather.uwyo.edu/upperair/sounding.html). Here, to develop thunderstorm model using SANCIS system all the data observation has been filtered from RAW data. In order to develop thunderstorm model, the researchers use three years observation in daily observation. The observation area in this study located in Sumatera island, Indonesia near West Java, Indonesia and Malaysia Peninsula.

2. Instruments

After the parameter input collected, the observation data *H* and *RSPWV* were used to develop thunderstorm model using ANFIS method. Here, ANFIS based on Human Expert model was embedded in SANCIS to predict thunderstorm activity over Sumatera, Indonesia (see Fig.1).

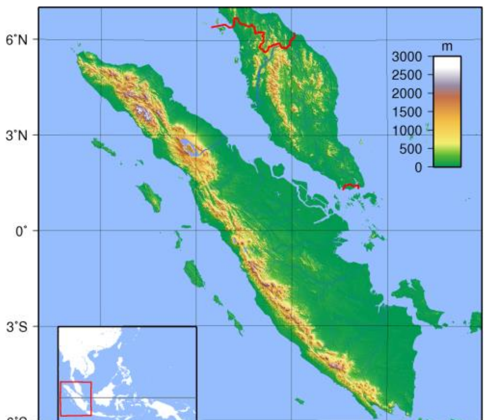

Figure 1. The location of observation data
(6°N, 5.8°E with elevation 17 m)

By using five data references to obtain thunderstorm model, SANCIS system can be calculated six days ahead with maximum error below 10% compared with observation data. Fig. 2 showed the flowchart data processing SANCIS system to obtain thunderstorm model data using one day a head observation. In this model, the data observation *H* and *RSPWV* in x(t) variable stand for nowadays observation, x(t-1), x(t-2), and x(t-3) is stand for yesterday, the day before yesterday, and two days before yesterday, respectively. Furthermore, the ANFIS Human Expert model was proposed to obtain thunderstorm model over SANCIS system.

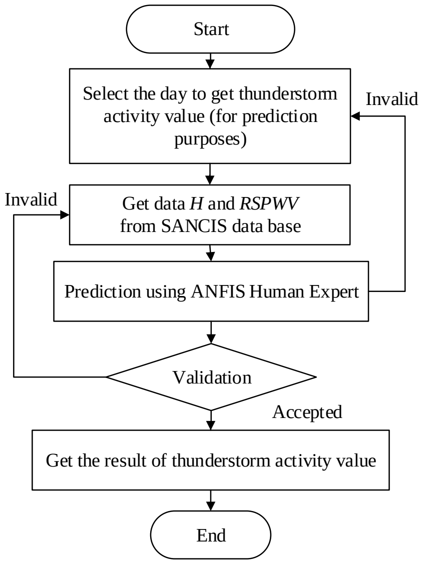

Figure 2. Flowchart data processing SANCIS

3. Technique of Data Analysis

3.1 Weather Research and Forecasting Environmental Modeling System (WRF EMS) Software

In order to validate thunderstorm model in SANCIS system, the researchers propose WRF EMS software to compare the thunderstorm activity. This software based on numerical weather prediction (NWP) and can be running under Linux platform. The WRF EMS is free software taken from University Corporation for Atmospheric Research (UNCAR) http://strc.comet.ucar.edu/software/newrems this software have four parts to obtain the result such as external data source, WRF Pre-processing system, WRF model and visualization (see fig 3).

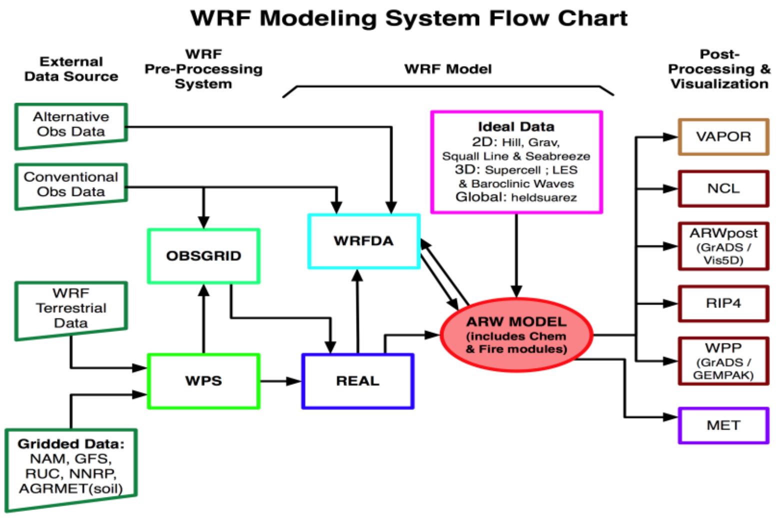

Figure 3. Flowchart WRF modelling to process the data (http://www2.mmm.ucar.edu/wrf/users/model.html)

Figure 3 shows the WRF EMS models used as a terrestrial data to get area observation including geographic coordinate and domain. Here, the source of external data has been given in WRFDA slot to pre-processing data. Furthermore, the processing and compiling of data using two primary information (such as geographic coordinate and domain prediction) was calculated in two modes 2D and 3D (numeric and figure).

3.2 Adaptive Neuro-Fuzzy Inference System (ANFIS) Human Expert (HE) for Thunderstorm Model

In order to assess thunderstorm phenomena in the Sumatera, the ANFIS Human Expert (HE) was proposed to estimate in SANCIS system. The ANFIS concepts to obtain thunderstorm model is located in Membership Function's (MF's) design over Fuzzy Inference System (FIS). Here, the MFs thunderstorm was designed from correlation input and output parameters. Furthermore, The HE concept is designed based on user experts combined with Gaussian function to improve training, testing, and validation results. Thus, the thunderstorm model based ANFIS HE method is great to predict thunderstorm activity based on knowledgement user expert. The mechanism of MF's ANFIS HE to obtain thunderstorm model is showed in figure 4.

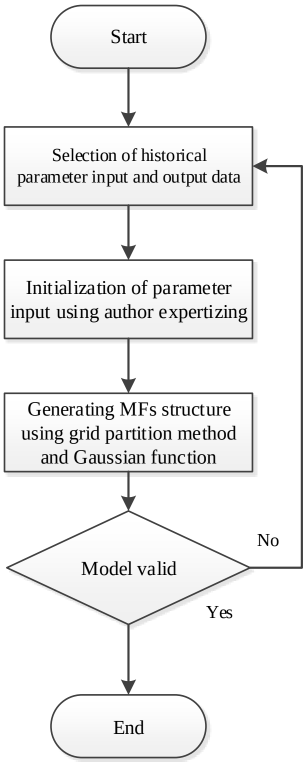

Figure 4. Flowchart MFs design of ANFIS HE

Furthermore, the best result from estimation ANFIS HE was chosen by iteration limitation and training time. However, in different case the iteration and training process does not guarantee during obtained estimation result. Thus, RMSE and Percent True value were calculated to obtain the best estimation result on testing and validation process. In order to obtain thunderstorm prediction event, the researchers use exponent Lyapunov chaotic time series as expressed in equation 1 (Suparta et al, 2017), where $\vec{X}(t)$ is prediction result, t is scalar index of estimation result (from ANFIS model), τ is time delay and m is collapse dimension.

$$\vec{X}(t) = \left[(x(t), x(t-\tau), \cdots, x(t-(m-1)\tau)\right] \qquad (1)$$

C. Findings and Discussion

1. Findings

In order to obtain thunderstorm model using ANFIS HE model, the researchers calculated the two parameters *H* and *RSPWV* with combined chaotic time series technique and six data reference. Furthermore, the researchers estimate thunderstorm model using ANFIS HE and validated by WRF EMS software. In this study, the setting time on WRF EMS software is started over three years (January 2015 ~ January 2018) to calculate thunderstorm model. Furthermore, The two model was compared (ANFIS HE on SANCIS and WRF EMS) started from today (1 January 2015) until six days a head (6 January 2013). The result shows a thunderstorm prediction value using SANCIS system and WRF EMS software has been tested. Both of the models were compared by real observation data in table 1.

Table 1. Comparison result between thunderstorm prediction model SANCIS and WRF EMS software

Step	Prediction Value (dBZ)		Observation value
	SANCIS	WRF EMS	
x(*t*)	22.263	24.437	0
t+1	24.266	25.428	0
t+2	36.532	37.512	1
t+3	35.529	36.987	1
t+4	22.263	23.662	0
t+5	36.379	37.869	1

Table 1 shows, the comparison result between SANCIS and WRF EMS thunderstorm prediction model has been calculated. Here, the prediction value from both models based on Radar reflectivity (dBZ) value. The dBZ unit is derivative from rain rate value over NOAA website (http://weather.noaa.gov/radar/radinfo/radinfo.html). In order to obtain SANCIS accuracy values the Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Percent Error (PE) and Correlation coef. (R^2) are proposed to assess thunderstrom prediction value. Here, the researchers assess thunderstorm prediction value based on two types such as SANCIS system and WRF EMS software. Table 2 showed the comparison result between SANCIS system and WRF EMS software.

Table 2. Parameter comparison between SANCIS system and WRF EMS software

Parameter	SANCIS	WRF EMS
RMSE (%)	0.779	1.278
MAE (%)	0.574	1.434
PE (%)	82.494	81.221
R^2 value	0.739	0.807

2. Discussion

The Result showed that SANCIS system is outperform than WRF EMS software with the lowest RMSE value of 0.499 % compared to WRF EMS software. In order to obtain the status of thunderstorm activity, Table 3 showed the intensity of thunderstorm activity over Tawau area. Here, the five range of minimum and maximum intensity value equal 0 and 1, respectively. The details of thunderstorm activity status as follow:

Table 3. The intensity index of thunderstorm activity

Activity value	The intensity thunderstorm
0 ~ 0.2	Clear
0.2 ~ 0.4	Low
0.4 ~ 0.6	Moderate
0.6 ~ 0.8	High
0.8 ~ 1	Extreme

The realization of thunderstorm model has been developed over Graphical User Interface (GUI) SANCIS system. In this system, the historical data and ANFIS HE has injected in the SANCIS system. The development GUI over SANCIS system has been sucessful to predict thunderstrom activity (see Fig. 5). Finally, the SANCIS system has been demonstrated and successfully applied to establish a thunderstorm early warning system that could provide accurate and reliable thunderstorm activity value.

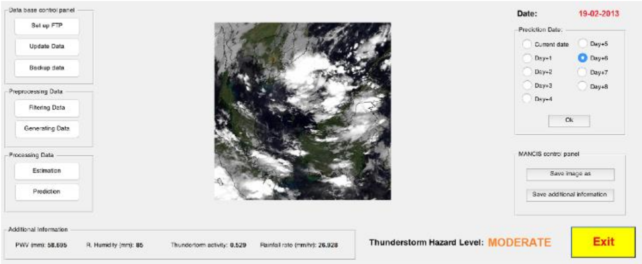

Figure 5. SANCIS GUI system to predict thunderstorm activity

D. Conclusion

The development of SANCIS system was successfully and validated with WRF EMS software. In order to obtain the highest accuracy and acquisition, SANCIS system used six data references with ANFIS HE. Here, the RH and RSPWV are used as an input model while the thunderstrom activity is used as a target model. The three years data from January 2015 ~ January 2018 was chosen to develop thunderstorm model. The result shows SANCIS systems is similiar compared WRF EMS software. Here, the comparison thunderstorm prediction model based on radar reflection unit (dBZ).

The comparison result shows SANCIS systems is outperform compared WRF EMS with the lower RMSE value of 0.499 %. Furthermore, the realization of SANCIS system has been successfully designed to obtain thunderstorm activity index. Finally, the result gives the confidence that the SANCIS system was successfully applied to establish a thunderstorm early warning system and also can be applied as a tool for meteorological studies such as storm weather monitoring and thunderstorm monitoring application.

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