

Decision Support System for Flash Flood Warning Management using Artificial Neural Network

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ABSTRACT

This paper presents an alternate approach that uses artificial neural network to simulate the critical level dynamics in heavy rain. The algorithm was developed in a decision support system environment in order to enable users to process the data. The decision support system is found to be useful due to its interactive nature, flexibility in approach and evolving graphical feature and can be adopted for any similar situation to predict the critical level. The main data processing includes the meteorological satellite image data, numerical weather prediction product as relative vorticity at 500hPa, the automatics weather station selection, input generation, lead-time selection/generation, and length of prediction.

This program enables users to process the critical level, to train/test the model using various inputs and to visualize results. The program code consists of a set of files, which can as well be modified to match other purposes. This program may also serve as a tool for real-time flood monitoring and process control. The running results indicate that the decision support system applied to the critical level of flood warning seems to have reached encouraging results for the risk area under examination. The comparison of the model predictions with the observed data was satisfactory, where the model is able to forecast the critical level up to 24 hours in advance with reasonable prediction accuracy. Finally, this program may also serve as a tool for real-time flood monitoring.

The potential benefit of a flash flood forecast depends on three main factors. Firstly its accuracy, which in turn depends on the accuracy of the forecast data, the observational data and the numerical weather modeling and updating procedures. Secondly the magnitude of the lead time it provides before critical levels are reached which can be improved by using quantitative precipitation forecasts from meteorological satellite cloud image, weather radar and numerical weather prediction models. Thirdly, the benefits depend on the effective use of the forecast information, for flood monitoring, flood warning, the operation of flood protection structures and the evacuation of people and livestock. This requires appropriate decision information in a timely manner to those who need it, where they need it, in a manner that is easy to understand.

Keywords : Decision Support System; Neural Network; Critical Level; Automatics weather station; decision support system.

1. INTRODUCTION

The rainy season started on May 5, 2006 about one and a half week earlier than normal. The rather active southwest monsoon prevailed over the Andaman Sea, Thailand and the Gulf of Thailand during the second half of May. Low pressure trough moved northward to lie across northern and northeastern parts during the end of the month. In addition, low pressure cell covered the lower northern and the upper central on May 21-23. These caused abundant rainfall in most part of Thailand particularly in mountain range between Uttaradit, Sukhothai and Phrae provinces. The maximum record for 24 hour accumulated rainfall was 330.0 millimeter at Lub Lae district, Uttaradit province on May 22. Flash floods, landslides and mudslides observed at Uttaradit, Sukhothai, Phrae, Nan, Lampang and Tak provinces on May 23 and 24. Severe damages i.e. dead and lost person were reported at several areas especially in Lub Lae, Ta Pla and Muang districts, Uttaradit province and Sri Satchanalai district, Sukhothai province and Muang district, Phrae province (see Figure 1). Flash floods triggered by days of heavy rain killed people and trapped thousands of others in northern Thailand. The floods, following three consecutive days of downpour, inundated several districts in the provinces of Nan, Phrae, Lampang and Uttaradit where more than 2,000 people were trapped and forced to climb on the roofs of their houses or in trees in Lablae district. Rescue teams with boats were deployed to the area to evacuate the stricken residents.

Flood in Thailand not only major flood but also flash flood has damaged both the life and properties since history of Thailand. The measures to reduce such flood damages can be by engineering structure and flood warning system. The flood warning system can immediately inform the people living downstream to take precaution before the flood reaching to villages. By this system the people suppose to make decision when the flood discharge would arrive and how much the time they have to evacuate to the safety locations. With the new technology of automatic weather station innovation and modern communication as well as GIS techniques, the decision support system for flood warning becomes more common and higher reliable forecasting.



Figure 1. The flood and landslide event at Phae Province (23 -24 May 2006).

The flood warning system developed in this study is aimed to install in upland watersheds where flash flood frequently occurred and to facilitate downstream communities people to be able to operate so that it can be used as a tools for making decision whether they suppose to evacuate or in what situation they should do in case of having heavy rainfall on the upstream.

The main target of the research is to design, verify and integrate the Automatic Weather Stations (AWS), remote sensing such as meteorological satellite image and Numerical Weather Prediction (NWP) product such as relative vorticity at 500 hPa . The all data from everything as above to the server was analyzed by using decision support system program and the process of real-time reporting situation by the network system was monitored and adjusted.

2. METHODOLOGY

The following procedures have been applied: 1) select the study area where flood frequently occurred, 2) design the system prototype for data transmitting and computer modelling in flood calculating. The system develops could be sent and received the data from automatic weather stations in every 5 minutes, 3) develop the early warning network between web server and users at local area via internet system. 4) develop decision support system for flash flood warning with people participatory.

2.1 Data Collection Platform

The new AWS (automatic weather stations) network in the warning Alert System installed by the Friends In Need (Of “Pa”) Volunteers Foundation. The purpose of this network consisting of AWS’s (3 stations) is monitoring the amount of rainfall. Part of these Stations are equipped with meteorologicals sensors (see Figure 2) as temperature, relative humidity, windspeed/direction, solar radiation and this information is useful for making meteorological forecast that are part of the material that is going to be employ in the warning alert system. The network works fully automatically or by including observer information. Also monitoring and administration of the stations, data communication, store data, alarm handling and process of the measurements are discussed, as the system is part of the national warning alert system a brief explanation of the inter institutional system is treated.



Figure 2. Data Logger and AWS.

2.2 Relative Vorticity at 500 hPa

Vorticity describes the rotation of a flow field and is, therefore, as divergence a property of the flow field. There is a contribution to upward motion where term (1) of the omega equation is characterized by vertically increasing values of vorticity advection. This is fulfilled where Positive Vorticity Advection increases with height or Negative Vorticity Advection decreases with height. From the synoptic point of view, the first condition is much more interesting than the second because the main cloud configurations are associated with Positive Vorticity Advection rather than Negative Vorticity Advection.

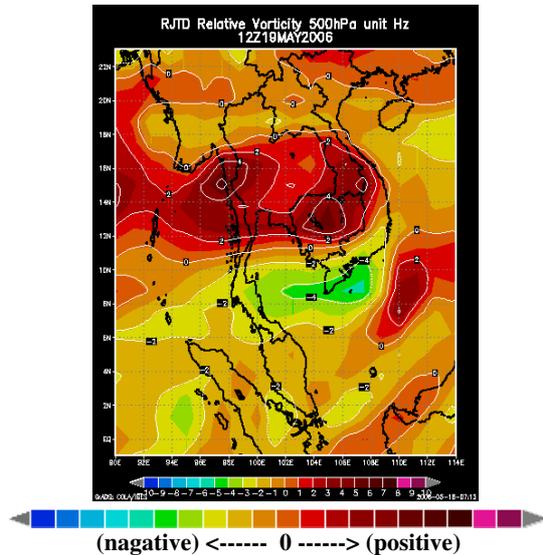


Figure 3. Relative Vorticity at 500 hPa.

$$\xi = \frac{\partial V}{\partial x} - \frac{\partial U}{\partial y} \quad \text{-----(1)}$$

$$\eta = \xi + f \quad \text{-----(2)}$$

ξ : relative vorticity

η : absolute vorticity

f : coriolis parameter

U : zonal wind component

V : meridional wind component

2.3 Meteorological Satellite Image

The simplest cloud measurement technique is the threshold method, in which an equivalent blackbody temperature or a spectral reflectance threshold is selected which distinguishes between cloud and non-cloud in infrared or visible satellite images. Information on cloud top temperature is obtained by comparing the observed brightness temperature with an atmospheric temperature profile - this approach usually underestimates the cloud height. Using a visible or near-infrared reflectance threshold works well for determining clear-sky ocean scenes that are free of sun glint. For example, you might classify a pixel as cloudy if the reflectance at a visible wavelength is greater than 8%.

Another straightforward approach employs two channels in combination. For example, the split window technique makes use of observations near 11 and 12 μ m to detect clouds over oceans. Cloud classification is accomplished by considering the 11 μ m blackbody temperature and the difference between the 11 and 12 μ m. Clear scenes have warm temperatures and brightness temperature differences that are negative, usually less than about -1° . Another simple two channel technique uses visible and infrared observations. In this approach observed visible reflectance and equivalent blackbody temperature are compiled in a 2-D array, and observations are then classified based on their relative brightness and temperature. For example, clear sky oceans would be warm and dark while convective clouds would be cold and bright. Automated classification of clouds is accomplished by either assigning thresholds or by employing maximum likelihood statistical techniques.

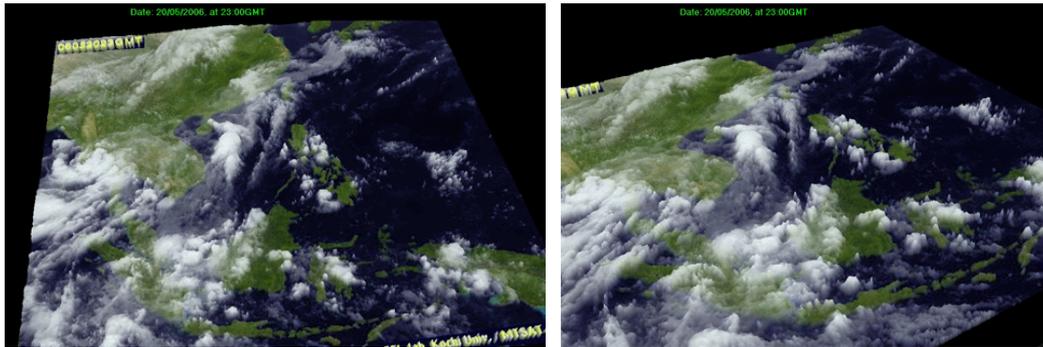


Figure 4. Meteorological Satellite Cloud Perspective image

2.4 Artificial Neural Network

ANN is a parallel and dynamic system of highly interconnected interacting parts based on neurobiological models. Here the nervous system consists of individual but highly interconnected nerve cells called neurons. These neurons typically receive information or stimuli from the external environment. Similar to its biological counterpart, ANN is designed to emulate the human pattern recognition function through parallel processing of multiple inputs i.e. ANN have the ability to scan data for patterns and can be used to construct non-linear models. Multi-Layer Perceptron Artificial Neural Networks have become widespread in recent years. Three layer networks with sufficient number of hidden nodes are usually applied due to the continuity of the relevant function. Every network contains an appropriate number of input and output nodes which is equal to the number of input and output variables, and the assumed number of hidden nodes. There is no effective rule for the estimate of the number of hidden nodes.

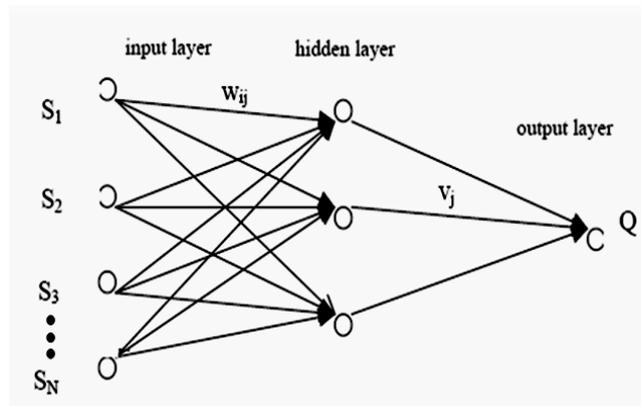


Figure 5. Multi-Layer Perceptron Artificial Neural Network scheme

The ANN nodes in neighbouring layers are linked via weighted connections. The values of those weights can be adaptively modified during the process of training the network. Shortly the Multi-Layer Perceptron network (see Figure 2) operates in the following way: signals S_i ($i=1, \dots, N$) from the input nodes (e.g. values of input variables normalized to 0-1 interval) are multiplied by proper weights w_{ji} ($j=1, \dots, K$), connecting the neuron from which signal has been dispatched and a suitable neuron in the second layer.

In the second layer the weighted sum of all the inputs are computed and then transformed by logistic function giving the output value of a neuron in the second layer. Afterwards the weighted signals z_j (multiplied by proper weights v_j), are transferred to the neuron of the third layer. In the neuron of the third layer the new weighted sum is computed and after de-normalization of the output, the sought (forecasted) value may be determined. This is a feed-forward network, which means that there is only one direction of the flow of information, from the input to the output layer.

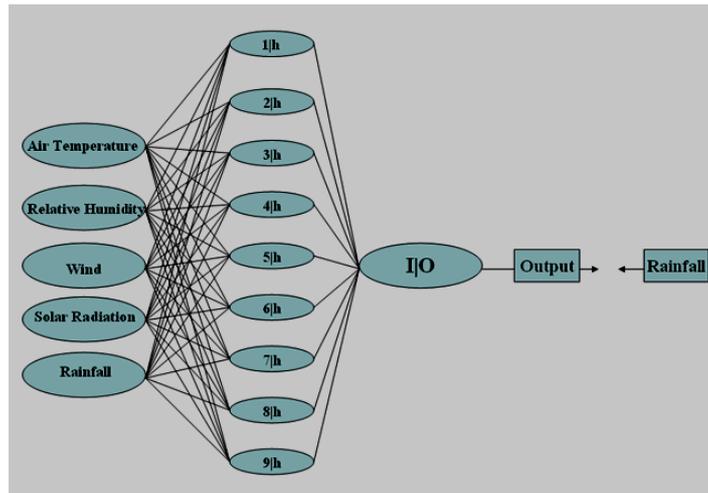


Figure 6. Artificial Neural Network scheme for rainfall

3. STUDY AREA

Uttaradit, Sukhothai, Phrae provinces (see Figure 7) have been selected to install and testing the system.



Figure 7. Study area: Uttaradit, Sukhothai, Phrae provinces.

4. THE RESULTS AND DISCUSSION

4.1 The prototype of flood warning system

Flood warning system designed and developed based on Global System for Mobile communications (GSM)/ General Packet Radio System (GPRS) system was installed at Uttaradit, Sukhothai, Phrae provinces (see Figure 8). GSM provides voice services (through a range of transcoders for differing speech qualities), Short Message Service (SMS), circuit-switched data (CSD) and High Speed Circuit Switched Data (HSCSD). GPRS creates a packet-switched overlay for the GSM network providing IP connectivity to the Internet and Intranets. The result is a cellular technology capable of supporting a very broad range of services.

4.2 Flood Warning Decision Support System

The decision support system for flood warning in the selected area was designed based on the relationship and critical condition of event with meteorological parameters which are determined in the decision support system program within 24 hrs (see Figure 10).

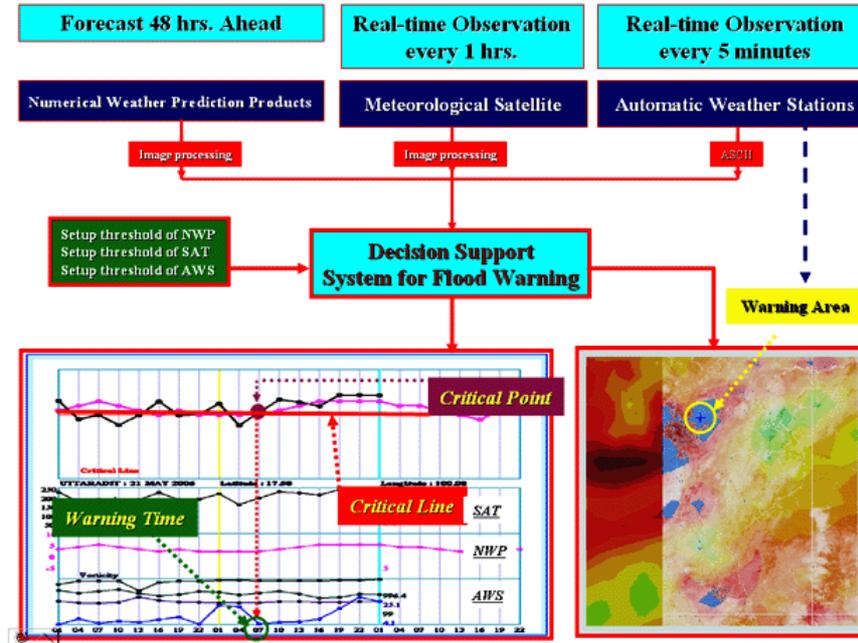
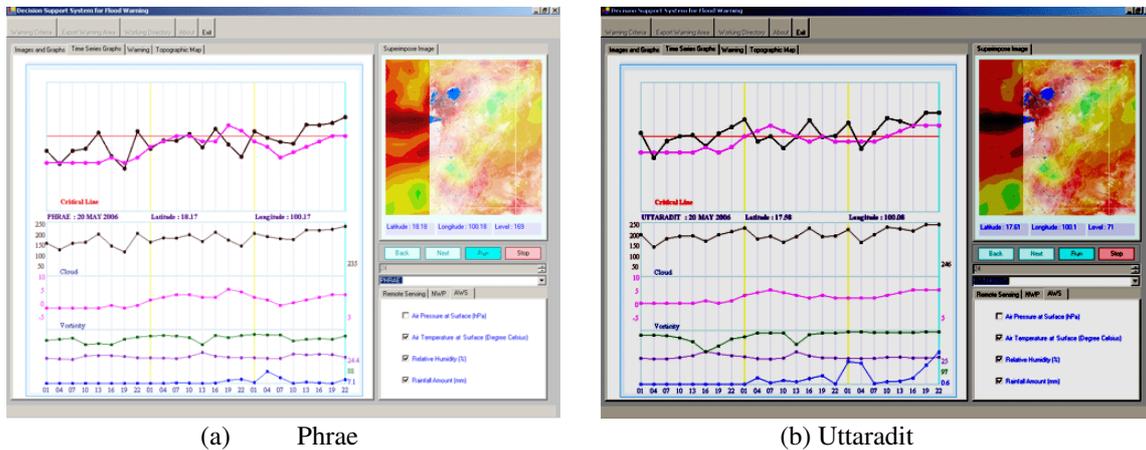


Figure 10. Basic flow chart of the DSS.

4.3 User Interface

In order to ease the users to interface with the system, the-user-interface (see Figure 11) was designed to present the data and flood situation. The critical line concept has been applied to inform flash flood situation.



(a) Phrae

(b) Uttaradit

Figure 11. Decision Support Program during heavy rainfall in May 2006

5. CONCLUSION

The principal conclusion from this research is that the new AWS network is an excellent Technology that permits a quantitative and qualitative improvement of the measurement of meteorological parameters in Uttaradit, Sukhothai, Phrae provinces. The introduction of this system is giving to risk area protection more information In type and detail to be an effective tool in providing advance notice of potential flooding So orderly evacuations can take place prior to the onset of flooding. will require a strong effort to assure the long term sustainability of the system.

Integrating human knowledge with modeling tools, an intelligent decision support system (DSS) is developed to assist decision makers during different phases of flood management. The DSS is developed as a virtual planning tool and can address both engineering and non-engineering issues related to flood management. The DSS is able to assist in: selecting suitable flood damage reduction options (using an expert system approach); forecasting floods (using artificial neural networks approach); modeling the operation of flood control structures; and describing the impacts (area flooded and damage) of floods in time and space. The proposed DSS is implemented for the Uttaradit, Sukhothai and Phrae provinces. This is pilot project and the results from the test application of DSS on May 2006 flood in Uttaradit, Sukhothai, Phrae provinces are very promising. The DSS is able to predict that. The decision support environment allows a number of “what-if” type questions to be asked and answered, thus, multiple decisions can be tried without having to deal with the real life consequences.

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7. REFERENCES

- [1] [Bar03] E. Barkan, E. Biham, N. Keller, “Instant Ciphertext-Only Cryptoanalysis of GSM Encrypted Communication”, Crypto 2003, August 2003.
- [2] Bennett, J.L. 1987. Tools for Building Advanced User Interface, International Business Machines Corporation, Reprinted with permission from *IBM System Journal*, Vol. 25.
- [3] Minutes: [GPRS Infrastructure IP Addressing; Working Party Meeting #1 \(held on 19th April 2000\)](http://www.ripe.net/ripe/wg/lir/gprs/007_0047_Minutes_GPRS_infra_addressing.html) (http://www.ripe.net/ripe/wg/lir/gprs/007_0047_Minutes_GPRS_infra_addressing.html)
- [4] Mitra, S.S., Decision support systems: Tools and techniques. John Wiley & Sons, New York, USA, 1986.
- [5] Nokia, “Using Special RANDs to separate WLAN and GSM/GPRS”, 3GPP TSG SA3 working document S3-040100, February 2004.