QUNATITATIVE PRECIPITATION FORECASTING USING CLOUD-BASED TECHNIQUES ON AVHRR DATA

L Billa, S.B. Mansor, A.R. Mahamud

SNML, ITMA,University Putra Malaysia,43400 Serdang, Selangor, Malaysia
biwal2000@yahoo.com , (shattri, arm)@eng.upm.edu.my

Commission V11, WG V11/5

KEYWORDS: Real- time, High resolution, Precipitation, Modeling, Classification, Processing, Estimation,

ABSTRACT

Tri-yearly recurrence of flooding in Malaysia has made floods the most important significant natural disaster in the country in terms of cost and damage to property. Many hydrological and hydraulic flood models have been implemented but are yet to meet the requirement of a near real-time flood forecasting. This study envisage the "Nowcasting System" through the operational coupling of quantitative precipitation forecasting (QPF) in remote sensing with hydrological and hydraulic oriented GIS to argument the problem. The paper presents the first phase of the study in the application of cloud model-based techniques in the extraction of precipitation from NOAA-AVHRR data for flood warning system. It discusses object oriented cloud classification techniques using Ecognition software to identify major cumulus cloud types. Cloud brightness temperature (TB) threshold levels are established and evaluated based on the digital number values in channels 1 & 2 of the AHVRR data. The intensity and dimensions of rain baring pixels are measured after a mask has been applied to extrude clouds and various enhancements and filtering processes. Estimates of expected precipitation are derived based on the assumption that every cloud pixel has a constant unit rain-rate of $3mm^{-h}$, which is appropriate for tropical precipitation over 2.5^o x 2.5^o areas around the equator.

1 Introduction

Malaysia experiences some form of flood every year due to its tropical location between latitude 7N and 5S and also it being in the path of the adverse effects the monsoon weather phenomena. It has two monsoons seasons a year, the north-east that occur from November to March and the south-west monsoons from May to September. In between the two monsoons are the two inter-monsoon periods   in April and October that are generally characterised by variable winds and thunderstorm in the afternoon. According to the history there is a serious flood vent every three years.

Over the years various flood forecasting and warning system based on an advanced hydraulic model has been applied in Malaysia. However, the systems have been limited to the forecasting of water levels in the major rivers. These forecasts proved inadequate for their inability to predict impending floods thus, they have had limited effect in reducing costs and damage to life and property due to flood (Fig1). As it's understood that it neither possible nor desirable to stop flood completely the is a shift in the approach to flood early warning. Hydrologists   are recognizing the practical limitations of rain gauges for measuring mean rainfall over large areas and inaccessible areas. They are increasingly turning to remote sensing as a possible means for quantifying the precipitation input in hydrological models, particularly in areas in of few surface gauges.
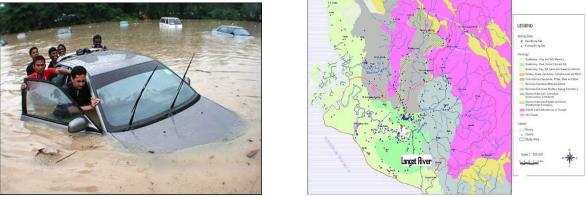

Fig1. Flash Flood in Malaysia 2003

Fig 2. Langat River Basin

Owing to the extreme cloudiness over Malaysia during heavy down pour, this study envisages the development of a Nowcasting system for the monitoring of Langat river catchment (Fig 2). The operational coupling quantitative precipitation forecasting (QPF) using cloud indexing and modeling based techniques with Mike 11 hydrodynamic oriented GIS in the bid to implement a fully automated simulation and early warning system (Fig 3). According to Karlsson (1999), Nowcasting defines forecasting in the approximate range +0-9 hours from observation time. However, due to data processing restrictions and present deficiencies in the shortest numerical weather prediction (NWP) model forecasts, special forecasting techniques are necessary for bridging the gap in the knowledge of weather evolution between the latest observation information and the information available from NWP models. He concluded that the challenge in Nowcasting is to utilize the latest observations together with models to improve very short forecasts.
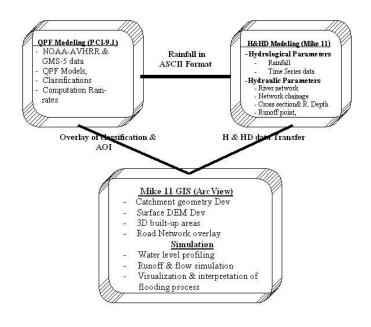

Fig 3. QPF& Hydrodynamic oriented GIS Flood Early Warning

2 Cloud base Modeling Techniques using NOAA-AVHRR

Satellite images are currently an in dispensable tool for forecasters to obtain a synoptic view of the distribution of cloud and cloud structures over region. Over the years various methods and techniques have been explored for rainfall estimation from cloud cover . Arkin, (1979) described the cloud indexing method to be based on the high correlations and probability fraction of cloud cluster colder than 235 K in infrared (IR). This model was initially developed for NOAA data and later adopted for Geostationary images. Rain days are identified from the occurrence of IR brightness temperature (T_B) below a threshold at given location. Details of this method are given by (Arkin,(1979), Arkin and Janowiak,(1991), Ba and Nicholson (1998), (Todd et al., 1995,1999).

The cloud model-based technique is another method that introduces cloud physics into the retrieval process for a quantitative improvement deriving from the overall better physical description of the rain formation processes. Details of these studies are found in (Gruber, (1973), Anagnostou et al., (1999), Reudenbach et al., (2001), Bendix, (1997, 2002)). This one dimensional cloud model, relates cloud temperature to rain-rate and rain area in convective stratiform technique (CST). Local clouds in IR T_B are screened to eliminate thin, non-precipitating clouds. The governing formulas are as follows:

Slope S is calculated for each temperature minimum T_{min}. Parameters defined as
$S = T_{1-6} - T_{min}$, T_{min} is Ave Temp of six closest pixels.
The rain area (A_r) is assumed to be five times the model up

$A_r = 5\pi r^2$, $R_{mean} = VRR/A_r$, $R_{mean} = 74.89 - 0.266T_c$, $A_r = \exp(15.27 - 0.0465T_c)$

Our study area, the Langat river basin catchment area is about 1, 988 km^2 The average annual rainfall depth is approximately 2,400 mm ranging from 1,800 to 3,000 mm. The highest rainfall occurs in the month of April and November with a mean of 280 mm. The lowest rainfall occurs in the month of June with a mean of 115 mm. The wet seasons occur in the transitional periods of the monsoons, from March to April and from October to November. In this study NOAA-AVHRR data was used because of moderately good spatial resolution of 1.1km and because of it repeated coverage of about 6 hr daily,

it will provide the real-time data that was required. NOAA-12 local area coverage (LAC) data was acquired at our local ground receiving station November 20, 2003 in monsoon season, as it will provide better understanding into rain baring clouds.

AVHRR data channels 1,2 and 4 were used to visually differential clouds based on the height and shape (Fig 4a). Five classes of features representing represent the land, sea, low stratus cloud, mid altos cloud, and high cirrus clouds (Fig.4b) using eCognition object-oriented image classification software to differential image object. Class objects were extracted using the infrared thermal channel 3,4,5 of the AVHRR data by knowledge-free automatic segmentation of the imagery, this showed a high contrast and allowed for better evaluation of brightness temperature and cloud heights. The segmentation technique of eCognition creates a hierarchical network of land, sea and cloud objects in different scales, which represents the image information. The classified clouds show attributes that correlate to their shape information, spectral statistics and relations to nearest objects. Only level 1 classification was performed using the nearest neighbour sampling. Due the limited spatial resolution of AVHRR data level 2 and 3 classification could not be performed as the involve sub object classification.
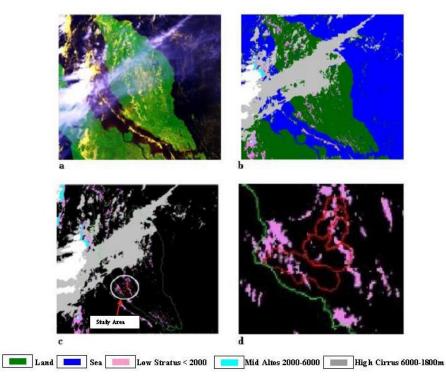

Land   Sea   Low Stratus < 2000   Mid Altos 2000-6000   High Cirrus 6000-1800m

Fig 4 Cloud Type Identification and Classification

Bi-spectral techniques based on the relationship between cold and brightness temperature of clouds were used to evaluate precipitation probability. The NIR and IR channels 3,4,and 5 of the data were processed for temperature and brightness. In an infrared (IR) image cold clouds are high clouds, so the colors typically highlight the colder regions Mid height clouds with T_B below 235k were identified as cumulonimbus cloud with a high probability to precipitate. Lower probabilities were associated to warm but bright stratus cloud and thin cirrus cloud that were cold but dull. The study area shows warm but bright non-precipitating stratus cloud (Fig 4c).

Cold clouds with temperature below 235k threshold value are taken as indication of rain. The intensity and dimensions of rain bearing pixels were measured after a mask has been applied and clouds have been highlighted (Fig 4d). Various enhancements and filters are then applied to improve the visual interpretation of the clouds. Rainfall is estimated based on the assumption that every cloud pixel has a constant unit rain-rate of 3mm^{h-1}, which is appropriate for tropical precipitation over 2.5^o x 2.5^o areas around the equator. Total cold cloud cover and the portion of the catchment covered by cloud determines rainfall intensity.

3 Conclusion

Cloud classification was performed using feature object oriented techniques on NOAA AVHRR data. Although the coarse resolution of 1.1km of AVHRR data did not allow for high-level classification, object orient classification however proved effective for the cloud type identification due to the

input of shape, texture and spectral information in the classification process through the multi dimensional input object functions. Rain- rates computed through this QPF process look good and promising; results have however yet to be verified, as study is still ongoing. This cloud multi feature object classification technique will require further study to improve the QPF process.

5 Reference

Anagnostou, E. N., Negri, A. J. and Adler, R. F.. 1999. A satellite infrared technique for diurnal rainfall variability studies. *J. Geophys. Res*., 104**,** 31477–31488.

Arkin, P. A., 1979 The relationship between fractional coverage of high cloud and rainfall accumulations during GATE over the B-scale array. Mon. Wea. Rev, 106, 1153-1171.

Arkin, P. A., and Janowiak, J., 1991 Analysis of the global distribution of precipitation. Dyn. Atmos Oceans, 16, 5-16.

Ba, M. B., and Nicholson S. E.,1998. Analysis of convective activity and its relationship to the rainfall over the Rift Valley lakes of East Africa during 1983-90 using the Meteosat infrared channel. J. *Appl. Meteorology*., 37, 1250-1264.

Bendix, J., 1997. Adjustment of the Convective-Stratiform Technique (CST) to estimate 1991/93 El Niño rainfall distribution in Ecuador and Peru by means of Meteosat-3 data. *Int. J. Remote Sensing,* 18, 1387-1394.

Bendix, J., 2000 Precipitation dynamics in Ecuador and Northern Peru during the 1991/92 El Niño: a remote sensing perspective. *Int. J. Remote Sensing*, 21, 533-548.
Gruber, A.,1973 Estimating rainfall in regions of active convection. *J. Appl. Meteorology*., 12, 110- 118.

Definien imaging ,2001. Ecognition -Advanced land useclassification using polarimetric highresolution SAR ,Vol. 2, No. 6, August 2001, http://www.gisdevelopment.net/application/environment/overview/envo0010pf.htm (20/03/04)

Karlsson ,K., Thoss, A and Dybbroe, A.,1999..High Resolution Cloud Product from NOAA AVHRR AND AMSU. Swedish Meteorological and Hydrological Institute (SMHI) S-601 76 Norrköping, Sweden

Todd, M. C., Barrett, E. C., Beaumont, M. J. and Bellerby, T. J.,1999 Estimation of daily rainfall over the upper Nile river basin using a continuously calibrated satellite infrared technique. *J. Appl Meterololgy.*. 6, 201-210

Todd, M.C., Barrett, E. C., Beaumont, M. J. and Green, J. L., 1995. Satellite identification of rain days over the upper Nile river basin using an optimum infrared rain/no-rain threshold temperature model. J. Appl. Meteorology. 34, 2600-2611.