Integrated Prediction of Interdisciplinary Model and Manage of Disaster Warning in Emergency Operation

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ABSTRACT

The major aims of this research are to integrate the multidisciplinary prediction model by way of interdisciplinary cooperation. In order to response rapidly in the emergency operation and to manage the disaster warning effectively, the rainfall forecast model, disaster prediction models and society-economic impact estimated model are collected to combine to form an integrated warning system. Some practicable products of the development and research in this project are used for disaster warning manages in Central Emergency Operational Center (CEOC) during the typhoon season in 2013. The results of emergency operation are confirmed that the research and development are effective in reality and worth to progress continually.

Key word: Interdisciplinary model, disaster impact

1. Introduction

The major targets of this project are to support the works in Central Emergency Operational Center (CEOC) and to satisfy the needs of decision making in emergency operation. In this purpose, the research and technology development are focus on the warning application of flood and land-slope disaster for the typhoon and heavy rainfall emergency operation.

The items of research and technology development include rainfall forecast combined the Quantitative Precipitation Estimation (QPE) form rain gauge and radar observations and the Quantitative Precipitation Forecast (QPF) from mesoscale weather model forecasting. The flood and slopeland disaster probabilistic models, 2-Dimension flood physical model and slope-stability physical model are injected into the integrated system to predict disaster occurrence. The society-economic estimated methods are developed to estimate the impact scale from disaster attack.

2. Multidisciplinary Model

A. Flood Probabilistic Model

The Flood Probabilistic Model was developed for real-time warning based on deterministic flood inundation mapping (Jang, et al., 2011). The statistics method can be expressed in terms of 24 hours accumulated rainfall (R) and parameter a/b as bellow function 1. The parameter a/b are statistics gathered statistics by flood investigation and 24 hours accumulated rainfall in grid space of 0.125°×0.125°.

$$\text{Flood Porbability} = 1 - 1/(1 + R^b \times e^a) \quad (1)$$

B. Slopeland Disaster Probabilistic Model

The Slopeland disaster probabilistic model was also developed in a form of function 2 with effective accumulated rainfall (R) and parameter a/b. The effective rainfall is defined that the accumulated period is exceed the limitation of 4 mm in 24 hours. The parameters are also gathered in the same grid space of 0.125°×0.125°, but for effective rainfall and slopeland disaster investigation.

$$\text{Slopeland Disaster Probability} = 1/(1 + e^{-(a+b\times R)} \quad (2)$$

C. 2-Dimensional Inundation Model

Huang et al. (2014) establish an efficient 2-D inundation model, incorporating the radar estimating precipitation and multi-scale computational method, to provide accurate resolution results. The model was used in this study with high resolution grid to verify the capability of flood warning and attempt to analysis the flood disaster impact of human, economy and society.

D. Slope-Stability Model

The Transient Rainfall Infiltration and Grid-Based Regional Slope-Stability Model (TRIGRS) is used for slopeland safety estimation in this study. This model was developed by USGS (Baum et al., 2002) and released in the internet already. TRIGRS implements the method outlined by Iverson (2000) to compute transient pore pressure, due to vertical infiltration, and attendant changes in factor of safety in a digital landscape. Baum et al. (2002) extended Iverson's method by adding a solution for an impermeable basal boundary at a finite depth, and adding a simple runoff-routing scheme to disperse excess water from cells where the application rate exceeds the infiltrability. The TRIGRS program allows the following input parameters to vary from cell to cell throughout the model: precipitation intensity, slope, soil depth, initial water-table depth, saturated vertical hydraulic conductivity, hydraulic diffusivity, cohesion for effective stress, angle of internal friction for effective stress, and total unit weight of soil.

E. Disaster Impact Estimation

The population distribution is used for disaster impact estimation. The investigating population is a form of GIS location points. The data have to transfer to the same grid space for probabilistic model (Figure 1). The disaster impact of probability model is driven by space probability and population. Moreover, the land-use investigations were used to estimate the disaster area in the different land-use categories counted the land-use area in the grid space of 5 meter transferred from the GIS polygon shape data.

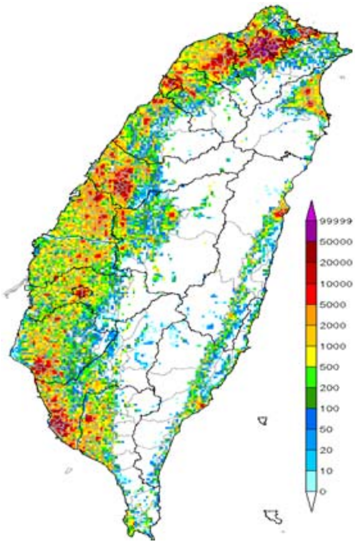

Figure 1. Grid population.

3. Result and Analysis

A. Analysis of Probabilistic Models Prediction

The slopeland disaster flood probabilistic models already operate every day, and the observation rainfall is updated for the hourly simulation. The results of 0-48 hours forecast were graphed per 3 hours in both probabilistic models.

Typhoon Soulik case in 2013 was examined to verify the forecast results of probabilistic models. The forecast results of slopeland disaster probability are shown in Figure 2. The major rainfall occurred in the mountain area of central Taiwan, when Typhoon Soulik passed through north Taiwan. The high disaster probability occurred after 12 hours and retained to 48 hours.

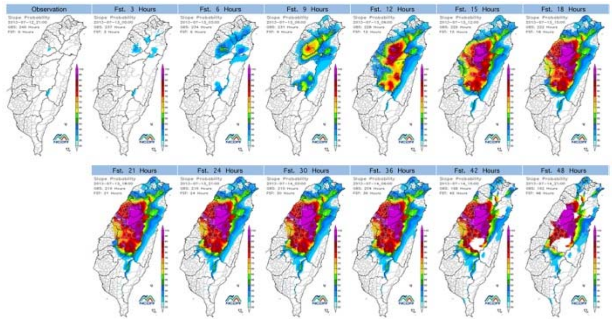

Figure 2. Slopeland disaster probability for 0-48 hours forecast in Typhoon Soulik Case.

The forest results of flood probabilistic model are shown in Figure 3. The high flood disaster probability is during 12 to 36 hours. After 36 hours, Typhoon Soulik already went away from Taiwan and impact of typhoon circulation also decreased.

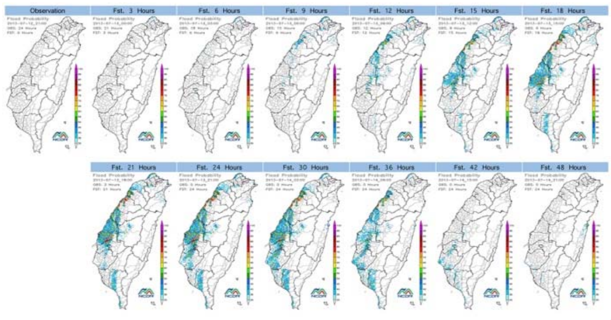

Figure 3. Flood probability of 0-48 hours forecast in Typhoon Soulik Case.

Compare to the disaster investigation (Figure 4), the actual flood is shown as blue area in county scale and slopeland disaster and broken road are shown as red and orange point. In comparison, the probabilistic models can capture the most occurrence of flood and slopeland disaster, but the flood probabilistic model still over-predict in the coast area of Miaoli county and Hsinchu county.

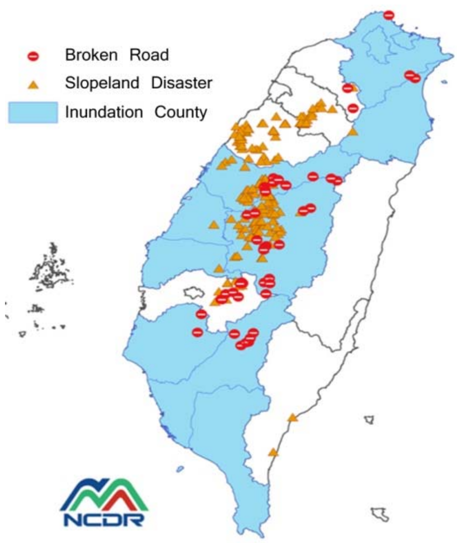

Figure 4. The disaster distributions in the whole peroid of Typhoon Soulik included the flood happened county (blue area), and the locations of slopeland disaster (yellow triangle) and break road (red circle).

Furthermore, the probability of disaster occurrence also can be used to analysis the society impact through the population analysis. The examined case is the heavy rainfall case in 2012 Meiyu season, and the accumulated rainfall, flood probability and disaster impact are shown in Figure 5. The 24 hours accumulated rainfall (Figure 5a) shows the heavy rainfall occurred in the north Taiwan and the mountain area of central and south Taiwan. In this case, the major flood disasters were happened in the north Taiwan caused by the sudden heavy rainfall at mid night. Hence, the high probability occurred in Taipei City, New Taipei City and Taoyuan County (Figure 5b). The disaster impact of population (Figure 5c and 5d) indicated that most residents are influenced seriously in those areas and towns.

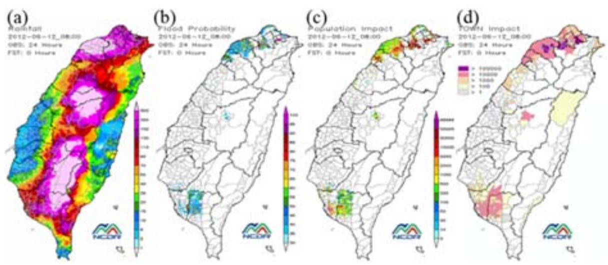

Figure 5. (a) 24 hours Accumulated rainfal, (b) flood probability, (c) grid distribution of population impact and (d) town impact on June 12, 2012.

B. Application of 2-D Inundation and Slope-Stability Models

In order to quickly estimate the flood and slope stability in Taiwan, all basin simulations are launched in the way of distributed computing at the same time. Total 51 and 25 basins were divided in 2-D inundation model and TRIGRS model, respectively. Both models are used 200 meters resolution for grid space. When all basins finish simulation, all results are combined and graph the flood depth (Figure 6a) and low safety index (Figure 6b) for scenario analyses.

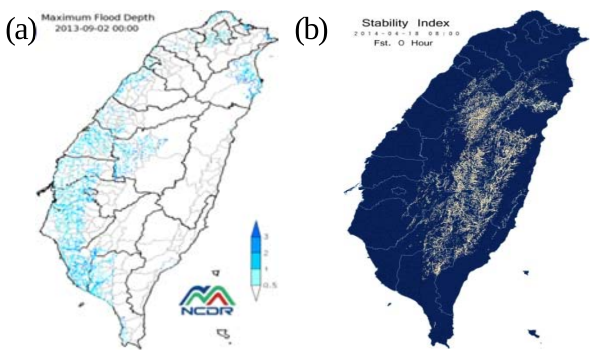

Figure 6. The Basins integrated graph of (a) 2-D Flood model and (b) TRIGRS model predictions.

In this study, the Typhoon Megi case was examined for 2-D inundation model simulation and disaster impact estimation. In this case, the major rainfall was occurred in Yilan County and made large flood area in that county. The comparisons of flood investigation and simulation are shown in Figure 7. The blue regions in Figure 7a are expressed the investigation area. The simulation flood depth distribution (Figure7a) is similar the most part of flood investigation near the coast area in Yilan County.

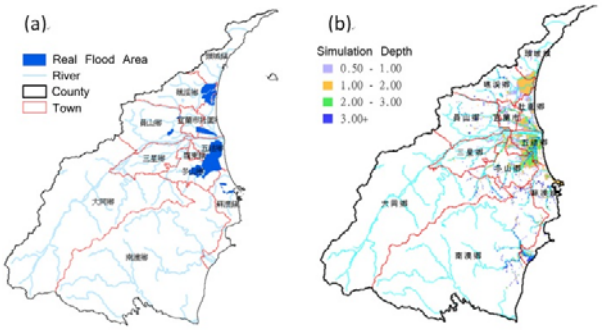

Figure 7. Inundation area of (a) investigation and (b) simulation during Typhoon Megi approaching Taiwan.

The simulation flood depth of 2-D inundation model was used to classify the landuse categories of inundation area, and the result of Typhoon Megi case was shown as Figure 8. When Typhoon Megi approach Taiwan and pass through Bashi Channel, the typhoon circulation made heavy rainfall in Yilan county. The major effects of flood area are on the agriculture area. The flood approximately covers an area of 1000 hectare in residential district.

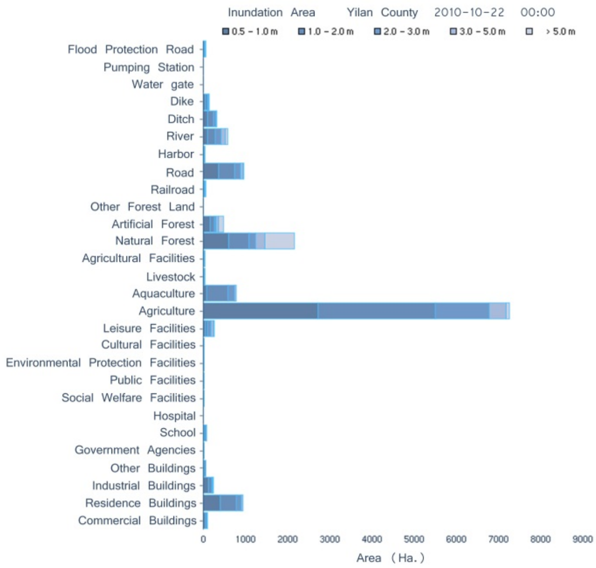

Figure 8. Inundation area of each landuse categories during Typhoon Megi approaching Taiwan.

4. Summary

Some practicable products of the development and research in this study were used for disaster warning manages in Central Emergency Operational Center (CEOC) during the typhoon season in 2013. The results of emergency operation are confirmed that the research and development are effective in reality and worth to progress continually. Although the 2-D inundation model and slope-stability model are still in the stage of development, these two models will provide more detail disaster scenario through the high resolution simulation before disaster happen in the next few years.

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