THE STUDY OF PREVENTION, MITIGATION AND EMERGENCY MANAGEMENT SYSTEM IN TYPHOON INFLUENCED AREA OF CHINA

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Key Words: typhoon disaster, Multivariate Compound Extreme Value Distribution, emergency management system, risk assessment

Abstract:

With global warming and sea level rising, the frequency and intensity of typhoon have been increasing. Every year, typhoon disasters cause severe economical loss and influence more than 250 million lives in China. Therefore, it is urgent to establish prevention, mitigation and emergency management system in typhoon influenced area.

Four parts will be discussed in this paper:

1. The lessons from 2005 Hurricane Katrina and 1975 Typhoon Nina. In 2005, hurricane Katrina attacked USA, causing 1200 deaths and 80 billion economic loss in New Orleans. In 1975, typhoon Nina induced 62 downstream dams collapsed and 26,000 deaths in China. Two catastrophes taught an important lesson: Katrina and Nina are not natural disasters, only when natural hazards combine with human hubris, disasters and catastrophes will come sooner or later. Analysising these two hurricane (typhoon), we can find: intrinsic factor — the problem of design criteria for coastal defences and dams; extrinsic factor — human, system performance and knowledge acquisition. In a word, the Multivariate Compound Extreme Value Distribution (MCEVD) can be used to obtain reasonable results rather than traditional methods, but the human hubris and failure of delivery system must be taken into account.
2. To establish the reasonable coastal defence design criteria, the MCEVD was used to predict 100-yr joint return period of water level with combination of typhoon occurring frequency, storm surge, flood peak runoff from upstream river and spring tide. This value is closed to 1000-yr design water level predicted by traditional annual maximum extrapolation following design code of China.

3. According to typhoon Sepat and Wipha transeferring 4.5 million people, we propose to construct refuge buildings against typhoon in coastal area instead of metastasising people and establish new design criteria of wind pressure for civil engineerings in typhoon influenced area.

4. The emergency management flow chart for relevant government to make decision is proposed.

Introduction

With the global warming and sea level rise, the intensity and frequency of typhoons also increased rapidly over recent decades. Recently, a German oceanographer Stefan Rahmstorf predicted that the sea level in 2100 would be 0.5-1.4 m higher than it was in 1990 (Stefan, 2007). Half a meter ocean level rise will force coastlines back by hundreds of meters, and the ocean disaster will be more and more serious.

In China all of the 10 coastal provinces and 6 inland provinces are influenced by typhoon induced disasters. In another words, more than 250 million lives and about 60 trillion (RMB) GDP are menaced by typhoon induced disasters which mainly contains strong wind, huge waves, storm surges, heavy rainfall and secondary disasters induced by typhoon such as flood, rock-mud flow, slide and so on.

In 2005, hurricane Katrina attacked coastal area of the U.S.A. causing fatalities and great economic loss in the city of New Orleans. One year later, China suffered heavy losses in several serious typhoon disasters. According to the 2006 tropical weather summary of China, typhoon Chanchu, which formed in May, caused damage to a deep water platform in South China Sea. Typhoon Utor, which was the last typhoon in this year, affected Xisha archipelago in China on Dec. 13th, and sank many ships. In August of 2006, some typhoons made landfall in the coasts of China, such as super typhoon Saomai, typhoon Bilis with 150 hour duration after landfall, and so on. In 2007, typhoon Sepat and Wipha made government transfer 4.5 million people, and they led to direct economic losses up to 120 billion RMB. The life and property losses in this year were the most serious in recent years. It is widely recognized that the frequency and intensity of typhoons have been increasing with global warming and sea level rising. One of the greatest future challenges in China will be to develop effective responses to an increasingly complex set of cumulative causes and consequences from typhoon induced disasters. According to the typhoon characteristics and potential for impact in different areas, it is urgent to establish the typhoon disaster zoning and prevention criteria system.

In view of the historical review of typhoon disasters and status quo of the prediction, prevention and mitigation of typhoon disaster in China, a new joint probability model----Multivariate Compound Extreme Value Distribution (MCEVD) is proposed in this paper and applied to disaster prediction of Shanghai.

Lessons from Hurricane Katrina and Typhoon Nina

The most severe typhoon was typhoon Nina in 1975, which induced catastrophic dam collapse in the inland province Henan. The rain storm brought 1631 mm rainfall in three days, which was twice more than the average annual precipitation 800 mm. Banqiao dam and some dams downstream collapsed. The flood spread over more than a million hectares of farm land throughout 29 counties and municipalities. This catastrophe led to 25, 000 deaths and 12,000,000 people were affected by flood and total economical loss reached to 10 billion RMB. Because this year was just in the Cultural Revolution, information communicated slowly and effective actions hadn't been done, which led to such a serious result.

Mentioning hurricane Katrina, the disaster prevention criteria is unscientific. And the operations and maintenance of the protection system don't perform well, which shows the human hubris. Failure of the New Orleans flood protection system is firmly rooted in extrinsic factors associated with human, organizational performance, and knowledge acquisition and utilization uncertainties (Rasmussen1997; Svedung and Rasmussen 2002; Bea 2006). This was not a 'natural disaster'. This was an 'un-natural' disaster caused by failure of the Technology Delivery System, which involved many different people and organizations developing a wide variety of malfunctions (e.g., decisions) over a long period of time.

From these two disasters, several lessons should be taught:

a. The Banqiao dam was designed to withstand a 1000-yr flood (306mm railfall per day). However, the typhoon Nina induced flood reached a 2000 year return period. This, to some extent, shows that prevention criterion for the coastal, offshore structures and estuarine cities predicted by traditional uni-variate extrapolation from annual maxima data sampling can not satisfy the increasing tendency of typhoon intensity and frequency.

b. Nowadays, about 50% sea wall along China coasts is unqualified in the design criteria. A lot of dams and reservoirs are in dangerous condition for typhoon induced floods. There are not reasonable design and disaster prevention criteria satisfying requirements of typhoon disaster or typhoon induced secondary disasters such as flood, mud-rock flow, landslide, et al.

c. Many coastal cities in China are threatened by typhoon each summer. There is a need to build complete system to prevent and mitigate the disasters. It is also important to make sure that the system will perform well.

In conclusion, there are two factors causing the disasters happened: intrinsic factor — the problem of design criteria for coastal defences and dams; extrinsic factor — human, system performance and knowledge acquisition. In a word, the Multivariate Compound Extreme Value Distribution (MCEVD) can be used to obtain reasonable results rather than traditional methods, but the human hubris and failure of delivery system must be taken into account.

Long term distribution of typhoon characteristics and typhoon induced extreme events-Theoretical Base of MCEVD

According to the randomness of annual typhoon occurrence frequency along different sea areas, it can be considered as a discrete random variable. Typhoon characteristics or typhoon induced extreme sea events are continuous random variables. Then the Compound Extreme Value Distribution (CEVD) can be derived by compounding a discrete distribution and the extreme distribution for typhoon induced extreme events along China coasts (Liu and Ma, 1980), after that it was used to analyze long term characteristics of hurricanes along the Gulf of Mexico and the Atlantic US coasts (Liu, 1982). During the past years CEVD has been developed into Multivariate Compound Extreme Value Distribution (MCEVD) and applied to predictions of typhoon induced disasters for coastal, offshore structures and estuarine city and prevention (Liu et al, 2002a, b, 2003, 2004). Both of CEVD and MCEVD have advantages: instead of traditional annual maximum data sampling, the typhoon process maximum data sampling is used, and typhoon frequency involved in the model. According to "Summary of flood frequency analysis in the United States"—"the combination of the event-based and joint probability approaches promises to yield significantly improved descriptions of the probability laws of extraordinary floods" (Kirby and Moss, 1987), MCEVD is the model which follows the development direction of the extraordinary floods prediction, hoped for by Kirby and Moss. It stands to reason that MCEVD is a good model for typhoon (hurricane) disaster prediction.

The theoretical base of MCEVD is as follows:

Let N be a random variable (the number of storms in a given year), with their corresponding probability $P\{N = k\} = p_k, \quad k = 1, 2, \cdots$; and let $(\xi_{11},...,\xi_{n1})$, $(\xi_{12},...,\xi_{n2})$...... be an independent sequence of independent identically distributed random vectors (the observed extreme sea environments in the sense defined above within the successive storms) with common density $g(\cdot)$. Then we are interested in the distribution of

$$(X_1, \ldots, X_n) = (\xi_{1i}, \ldots, \xi_{ni})$$

where ξ_{1i} is the maximum value of $\xi_{1j}, 1 \le j \le N, N = 1,2,......$

It represents the maximum annual value of the principal variable, together with the simultaneously occurring values of the concomitant variables. There is a reasonable approximation in definition of $(X_1, \ldots, X_n)$, the case of N=0 should be neglected, because no extreme value of interest can occur outside the storm when N=0.

When multivariate continuous cumulative distribution is $G(x_1, \ldots, x_n)$, then we can derive the MCEVD as:

$$F(x_1, \ldots, x_n) = \sum_{i=1}^{\infty} p_i \cdot i \cdot \int_{-\infty}^{x_n} \ldots \int_{-\infty}^{x_1} G_1^{\,i-1}(u) g(u_1, \ldots, u_n)\, du_1 \ldots du_n$$

where $G_1(u_1)$ is marginal distribution of $G(x_1, \ldots, x_n)$, and $g(u_1,...u_n)$ is density function.

Prediction of disaster prevention for design water level of Yangtze River for city Shanghai

There are two types of cities influenced by typhoon, which means estuarial city and coastal city. The city situated in estuary, whose design water level considering upstream flood, huge waves, storm surge induced by typhoon, and simultaneously astronomical spring tides was much higher than current criteria. There has the same situation in coastal city which don't consider upstream flood.

Shanghai City is located at the estuarine area of the Yangtze River in China. Historically observed data shows that the surges induced by typhoons and the flood peak run-off from Yangtze River coupled with the astronomical spring tide have caused significant losses of lives and properties to Shanghai City. Combined effect of storm surge, upper river flood and spring tide on the coastal structures is the prime factor for disaster prevention (Liu, et al., 2004).

Based on the traditional univariate annual maxima extrapolation method, the 1000yr return period disaster prevention design water lever for Shanghai City is 5.86 (m). But No.4 typhoon in 1981 had caused the water level as high as 5.74 (m). Obviously, the univariate extrapolation design water level neglects the contribution of the random combination of typhoon frequency, storm surge, flood and astronomical spring tide.

Daton Hydrological Station is located at the upper river of Yangtze River, 642 km from Wuson Oceanologic Station near Shanghai City. The observed water levels of flood at Daton station are not influenced by typhoon surge from sea side. Data of water level collected at the Wuson Station from 1970 to 1990, and the data of flood at the Daton Station are used in this study.

Observed water level at Wuson station during typhoon season (h_w) can be divided into three components:

1.The hourly harmonic analyzed tide (h_a) obtained from 63 harmonic constants model during 1912~1987. Because there are different uncertainties included in harmonic analysis (such as uncertainty induced by the choice of different numbers of harmonic constants, uncertainty in different duration of observations, uncertainty in analyzed harmonic constants from different period of observations, et. al), so that for the following multivariate joint probability study the astronomical spring tide would be considered as random variables.

2.The flood peak run-off from Yangtze River (h_f) can be obtained by linear regression equation $h_f = 7.67 \times 10^{-6} Q_D - 0.19^*$, where Q_D is observed flood peak volume (m^3/s) at station Daton in 24 hours before the typhoon occurring Shanghai sea area.

3.The typhoon induced storm surge (h_s) can be obtained by $h_s = h_w - h_f - h_a$.

It can be seen from the discussion that the annual typhoon occurring frequency varying from year to year is fitting to the Poisson distribution. The typhoon induced storm surge, simultaneous rise of water level by flood run-off from Yangtze River and astronomical spring tide are continuous variables. Therefore, the MCEVD can be used to predict disaster design water level for Shanghai city.

The total 72 groups of simultaneous h_f, h_s and h_a are used to study trivariate joint probability.

Diagnostic check shows that h_a, h_f and h_s fit to generalized extreme value distribution (See Fig.1,2,3).

Fig 1. Diagnostic check of spring tide

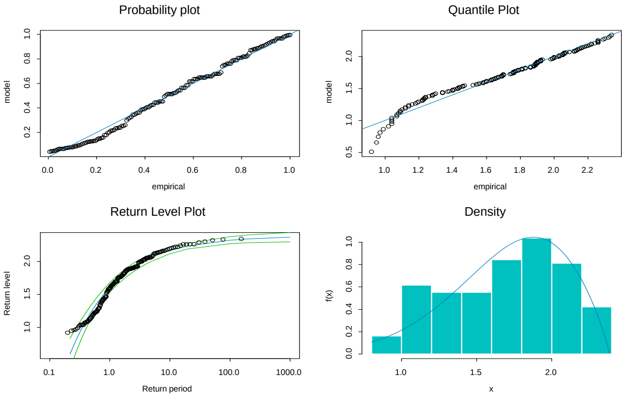


Fig2. Diagnostic check of flood

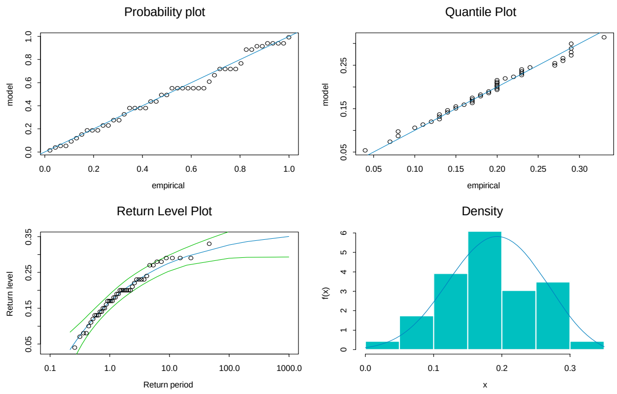
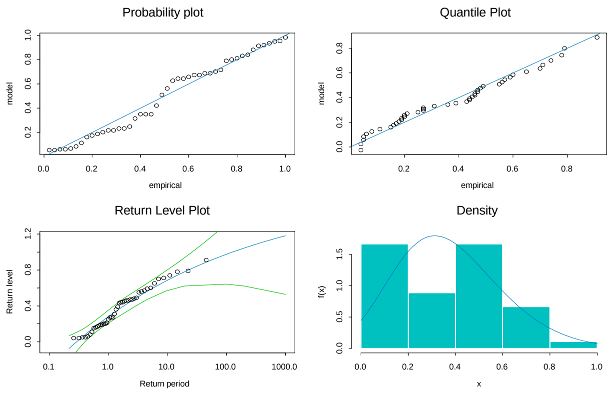


Fig3. Diagnostic check of storm surge



In this example, the design water level with 100-yr joint return period is obtained by using the data sampling dominated by the extreme storm surge with concomitant flood and tide. (See Tab.1)

Tab. 1 Estimated disaster prevention design water level for Shanghai city

Joint return period (years)	Flood surge (m)	Storm surge (m)	Spring-tide (m)	Design water level (m)
100	0.43	1.32	4.14*	5.89*

* at Wuson datum plane.

Tab.10 shows that the 100-yr joint return period design water level predicted by MCEVD is close to that of the 1000-yr return period water level predicted by the traditional univariate extrapolation method for Shanghai .

Disasters and transferring people

In the past year 2006, typhoon disasters were especially serious. Five main typhoon disasters brought about 1600 deaths and disappearances, affected 66.6 million people. The economical loss reached to 80 billion RMB and influenced agriculture areas totaling more than 2800 thousands hectares. Among these disasters, typhoon Saomai induced 3.76m surges and 7m waves, caused 240 deaths, sunk 952 ships and damaged 1594 others at Shacheng harbor. The 2006 typhoon disaster detail can be seen in Table 2.

Tab. 2 2006 typhoon disaster detail

Typhoon name	Maximum Wind (m/s)	Influenced Provinces	Influenced, Agriculture Area (thousand hectare)	Influenced Population (million)	Death & lost population	Economical Loss(RMB) (billion)
Chanchu	45	Guangdong,Fujian, Zhejiang	368.96	11.06	35	8.56
Bilis	30	Fujian, Guangdong, Hunan, Guangxi, Zhejiang, Jiangxi	1170.38	29.85	849	32.99
Kaemi	40	Fujian, Guangdong, Hunan, Guangxi, Zhejiang,Jiangxi, Anhui, Hubei	397.56	8.42	64	5.89
Prapiroon	35	Guangdong,Guangxi, Hainan	569.43	11.11	75	8.23
Saomai	75.8	Fujiang, zhejiang, Jiangxi, Hubei	223.16	5.99	570	19.49

In the summer of 2007, typhoon Sepat and Wipha made huge economic losses to China. It was reported that direct economic losses reached to 120 billion RMB. Although it is surprised that we lose so much, we cannot neglect that we also waste power and money in the process of transferring 4.5 million people from disaster areas in a large scale.

Japan is also a country which frequently influenced by typhoon. Though it has economic losses caused by typhoon, Japan don’t often transfer people from disaster areas in a large scale, it replace with concentrating people in some firm refuge buildings. In the areas which influenced by typhoon, Okinawa, for example, most of their houses are wind-resisting, even if they stay at home, they also can avoid attack of typhoon.

The method used in Japan gives us an enlightenment. In China, especially in the areas influenced by typhoon, we should construct refuge buildings against typhoon replacing transferring people in a large scale. And we should build more reasonable wind pressure criteria in typhoon influenced areas.

Emergency management system

Typhoon disasters and induced secondary disasters may lead to some social problems, for example, social order chaos, plague raging and prevalent, shortage of daily necessities causing high price, which make a strong impact on people's life. Meanwhile, typhoon disasters can make many investors create fear of investment in typhoon induced area. Nowadays, city community safety system has already existed in China, however, there are many serious maladies in the system, which mainly involve deficiency of rules, inadequate monitoring, communicating information slowly and lack of emergency management system. As we all know, city community safety system is a very complicate system. It is not only organized by hardware and software, but also need right human performance. The disaster of New Orleans just caused by unreasonable human performance. Any problems of hardware, software as well as human reliability could result city community safety system being out of control. It is clearly that the relationship of three factors is in series. According to OR gates definition, the mathematical model can be written as follow:

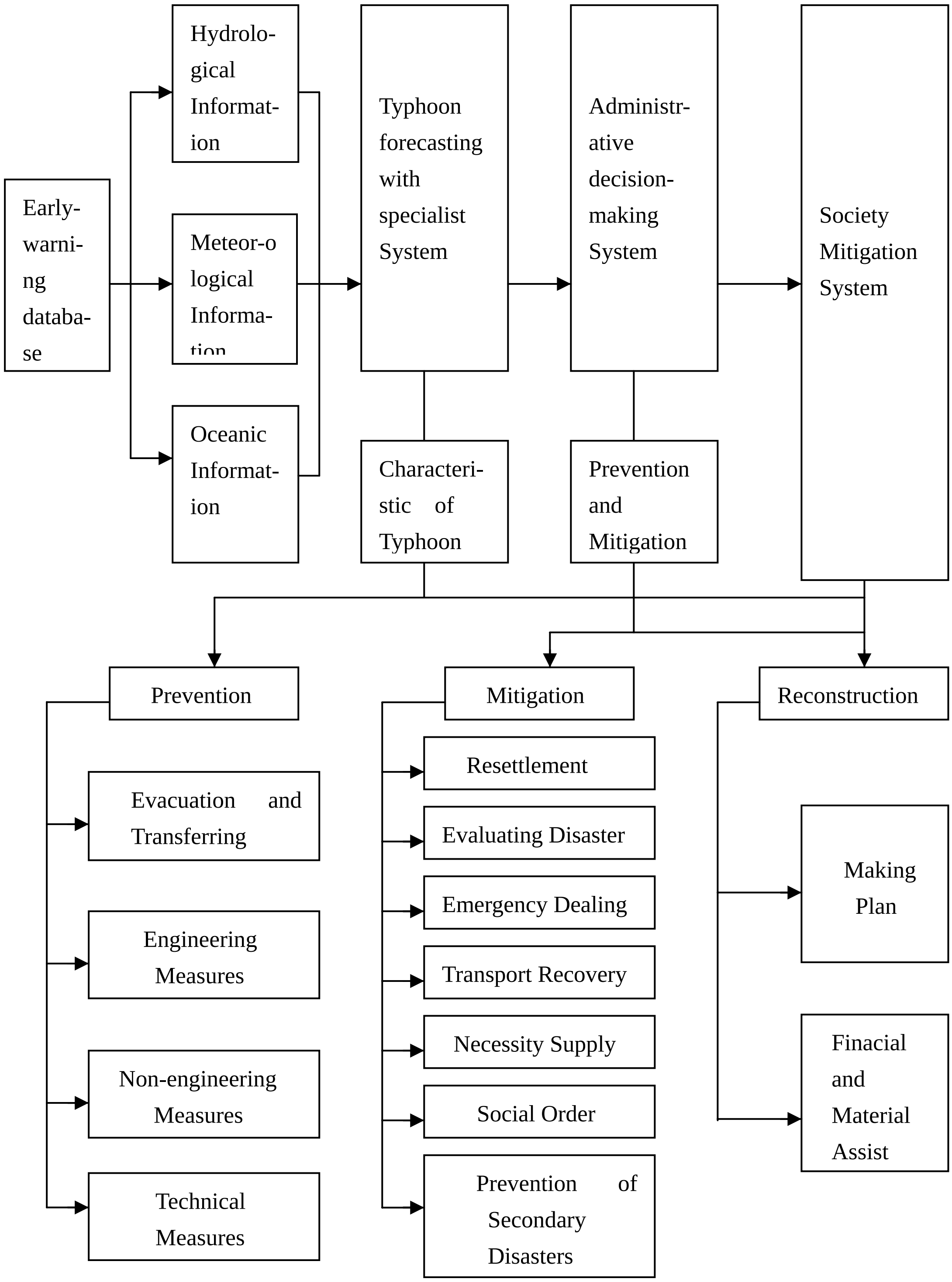
$$R_s(t) = \prod_{i=1}^{3} R_i$$

Where $R_s(t)$ is the system reliability and R_i presents the reliability of the serial sections.

And we should notice the importance of human performance.

So there is a need to build effective emergency management system and to improve ability of crisis management. According to prevention, early-warning, rescuing and reconstruction these four link, it is important to build emergency management system to resist typhoon disasters. (See Fig.4).

Fig4. Emergency Management System



What governmnet should do consist of three parts:

1.Strengthen the study of typhoon. It is important to take full use of collecting data to make analysis and do research. Correcting unreasonable current criteria and considering the most serious situation are also the key to prevent the typhoon disaster.

2.Connect building typhoon forecast system with prevention and mitigation command system. Strengthening numerical forecast and making reasonable analysis will give a hand to the early-warning of typhoon disaster. We should continually correct, improve and perfect the relationship between early-warning system and prevention, mitigation command system, which makes an effort to protect people.

3.Build systemic emergency management system. Governments at all levels should form connection between each link, build high-level comprehensive emergency management system. Government should play an important role in the prevention and mitigaiton of typhoon disaster.

Conclusion

China is a country which frequently influenced by typhoon disaster. We use the theory of multivariate compound extreme value distribution which is based on the combination of the typhoon process maxima data sampling to make joint probability analysis of typhoon induced extreme sea environments. According to this theory, governments should build scientific emergency management system for the prevention and mitigation of typhoon disaster.

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