Improved Stochastic Simulation Technique and Its Application to the Multivariate Probability Analysis of Typhoon Disaster

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ABSTRACT

In recent years, typhoons (hurricanes) in categories 4 and 5 have increased obviously in all of the ocean basins. Some landfalling intense typhoons (hurricanes) such as Saomai2006 and Katrina2005 made serious damage in coastal areas. So the study of typhoon (hurricane) disaster prevention based on probability analysis has been a subject of increasing interest. In this paper, a new Stochastic Simulation Method (SSM) based on the combination of the theory of Multivariate Compound Extreme Value Distribution (MCEVD) and Importance Sampling Procedure (ISP) is proposed. The proposed method is applied to the probability analysis of typhoon disaster in estuarine city----Shanghai. Study shows that, the new SSM developed toward theory of MCEVD is the efficient method for solving the joint probability problem of non-Gaussian and correlated multivariate variables and yields reasonable calculated results.

KEY WORDS: typhoon, probability analysis, multivariate compound extreme value distribution, stochastic simulation method, importance sampling procedure.

INTRODUCTION

With the increasing disasters induced by typhoon, it is more and more important to develop a reasonable prediction model for typhoon disaster. In this research field, there are two important problems: on one hand, the typhoon process is so complex that it is difficult to find an absolutely accurate model to describe its features; on the other hand, for some intricate high dimensional models, it is impossible to get the analytical solutions. However, the serious typhoon disasters have received considerable attention from different experts during the past several decades (Russell, 1968, 1971; Batts et al. 1980; Georgiou et al. 1983; Twisdale and Dunn, 1983; Vickery and Twisdale, 1995; Casson and Coles, 2000). In most of the studies, Stochastic Simulation Method (SSM) were used to simulate the meteorological parameters of typhoon, and typhoon wind speeds with some return period were calculated by using some wind-field models and filling models. In 1980, a new type of probability model----Compound Extreme Value Distribution (CEVD) was proposed by Liu and Ma (Liu and Ma, 1980), and it was successfully used in the study of long term hurricane characteristics along U.S. coasts (Liu, 1982). Then the model has been developed into Multivariate Compound Extreme Value Distribution (MCEVD) (Liu, Wang and Pang, 2006). But when the dimension is higher than 3, finding theory solution will become unpractical. In this paper, an improved SSM based on MCEVD is developed. Using the new method, long term typhoon characteristics in Shanghai will be analyzed. The rest of the paper is organized as follows: the methodology is introduced in Section 2; the application of the improved SSM is in Section 3; Section 4 offers the summary.

SIMULATION METHODOLOGY

Monte Carlo method

The joint probability analysis of typhoon characteristics is actually a solution process of some kind of multivariate integral:

\[ F(x_1, x_2, \ldots, x_n) = \int_{\Omega} \cdots \int f(x_1, x_2, \ldots, x_n) dx_1 dx_2 \cdots dx_n \quad (1) \]

where, \( \Omega \) is the joint probability domain obtained from some limit state