1 Introduction

1.1 Natural hazards and disasters

Every year, millions of people are under the influence of natural hazards (e.g. earthquake, volcanic eruption, cyclonic storms or drought). In the areas where vulnerable groups of people are exposed, these extreme natural events result in natural disasters (Blaikie et al. 2003), which are becoming more expensive and deadly.

The increasing in exposure to stronger storms, to longer flood or drought seasons is slowing down people’s efforts to improve their incomes and living conditions, according to United Nations Development Program (UNDP 2007). Because social processes and human-environmental interactions are significant factors in causing disasters (Blaikie et al. 2003), more lethal and costly extreme events is noticeable breakdown of unstable development (Frerks 2004). Rapid population growth, unplanned urbanization, development within high-risk zones, under-development, environmental degradation climate change and pressures on natural resources are driving forces, which have increased the vulnerability of the population to natural hazards and their consequent disaster (Holmes et al. 2005). In many developing countries, these agents are threatening the economy, population, sustainable development, and holding back fulfillment of Millennium Development Goals (Oanh et al. 2011).

1.2 Hurricanes and their impacts

Hurricane, also referred to as typhoon, or tropical cyclone are different names for the same phenomenon, that is a cyclonic storm system initiates over the seas. The resulting disasters have enormous human, economic and social consequences; affect numerous sectors (e.g. agriculture, aquaculture, industry); bring about billions US dollars of property damages. In addition, storm surge and large waves generated by typhoons can erode the beach and dune system and reshape the coastal landscape (Brettschneider 2006).

In developing countries, where 80% of the world’s largest cities are situated (Bendimerad 2004) and 90% of global population growth is taking place (World Vision 2009), the research showed that the deadliest typhoons usually happen. It likely expresses the rising populations, and more people living in hazardous with insufficient protection or even defenseless coastal zones (UNISDR 2008). Although loss of life has been significantly decreased in the industrialized world by successful prevention and preparedness plans, the richest often pay the highest financial losses due to great economic values of existing properties and high insurance levels in storm-prone regions (Emanuel et al. 2006).

1.3 Hurricane risk reduction

An easy to understand definition of hurricane risk is the estimated degree of threat facing a vulnerable group of people through exposure to hurricanes (World Vision 2009). The more susceptible the community (in various means, such as physically, economically, environmentally, or socially) the more expensive and deadly the typhoons. While hurricanes are unavoidable, their risk can be considerably lessened. It can be done either by decreasing the vulnerabilities and/or by increasing the capacities of the affected population to withstand typhoons, that is, their resilience.

Numerous approaches have been executed to lessen hurricane risk, including both structural and non-structural methods. In developing world, because of the limited available funds, equipment and technology, risk reduction mainly focus on non-structural ways by decreasing communities’ vulnerability as well as achieving sustainable development and poverty reduction (UNISDR 2012). They include protection of environmental resources, appropriate building technologies and regulations, proper land use planning based on vulnerability and...
capacity assessments, installation of early warning systems and signals, community awareness and preparedness plans, disaster simulations and evacuation practices, sufficient resources to drive and support an effective risk reduction agenda (UNISDR 2008).

On the other hand, almost all developed countries rely on a technical system to resist hurricanes, including both structural and non-structural methods. Structural solution is basically a sufficient number of proper-design coastal defense structures (i.e. hard engineering methods such as sea walls, floodgates, revetments, and offshore breakwaters), which can cope with the impacts of severe typhoon winds and storm surges at a certain level. Non-structural techniques are based on the successful hurricane early warning programs and predictive models of morphological impacts induced by extreme typhoons. They include soft engineering approaches (e.g. beach nourishment, sand dune stabilization, beach drainage), advanced building codes and their enforcement, master planning of coastal zone, increasing the effective of preparative solutions (e.g. evacuation strategies), and giving more helpful warning time for hurricanes.

1.4 An example of Vietnam

Vietnam is located in the East Asian monsoon sub-system. The country is affected by various types of natural hazards. Because more than 70% of the population is exposed to these hazards (Oanh et al. 2011), the consequent disasters have brought about remarkable human, environmental or financial losses. From 1990-2009, the annual number of death and evaluative total economic toll due to natural hazards was 457 and 1861.5 million US$ Purchasing Power Parity (PPP), respectively. This financial loss was equivalent to 1.31% Gross Domestic Product (GDP) (Harmeling 2010). In some areas (e.g. central region of Vietnam), vulnerability to disasters is a crucial element in the continuance of indigence. The majority of people living in these areas are considered as being especially prone to hazards because they have scanty disaster risk reduction methods (e.g. robust, disaster-resistant housing) and primarily rely on natural resources (World Vision 2009).

Located in one of the five storm-prone areas of the Asia Pacific region, with a long coastline of approximately 3440 km (Oanh et al. 2011), Vietnam has annually affected by flooding, and frequently by hurricanes. On average, there are six to eight typhoons each year (UNDP 2007). Acknowledging the country’s vulnerability, over recent years Vietnam has made great efforts to relieve poorness and verge upon achieving the Millennium Development Goals. Because the Vietnamese government notices the close relationship between vulnerability to natural disasters and poverty, a considerable amount of money have been spent to support various risk reduction campaigns. For example, from 2009-2015, $143 million would be paid out to address climate change only (World Vision 2009).

Acknowledging the country’s vulnerability, over recent years Vietnam has made great efforts to relieve poorness and verge upon achieving the Millennium Development Goals. Because the Vietnamese government notices the close relationship between vulnerability to natural disasters and poverty, a considerable amount of money have been spent to support various risk reduction campaigns. For example, from 2009-2015, $143 million would be paid out to address climate change only (World Vision 2009).

Figure 1 shows the geographic range of the East Sea - the ocean region that has directly effects on Vietnam.
2 Problem definition

2.1 Hurricane risk assessment

When typhoons hit the coast, they bring along many devastating impacts. As hurricanes near land, their intense winds produce storm surges - the rising walls of ocean water sweep through the entire affected coastal regions. This wind-induced surge is the most destructive and significant effect from a typhoon. It has been estimated to account for most of human losses, i.e. nearly 90% of all hurricane-related injuries and fatalities throughout history. After typhoons come ashore, they generate heavy precipitation that cause tremendous freshwater flooding in rivers and urban areas. These floods afterward can also trigger landslide along riverbank as well as mountainous and hilly regions. In several cases (e.g. Hurricane Floyd or Hurricane Mitch), loss of lives and destruction of properties mainly originate from inland flooding.

However, although typhoon-induced rainfall and its implications cannot be ignored, almost all existing hurricane risk assessment techniques associated with only typhoon winds (Emanuel et al. 2006). The underlying reason is currently, knowledge of hurricane rains have not yet reached to a certain level that can be a reliable basic of trustful rainfall predictions. In addition, historical records of typhoon winds are much more complete and therefore, extensive enough to make effective evaluations of hurricane risks.
2.2 Historical typhoon records

One meaningful approach to assess typhoon risks, which can occur at a specific location, is to analyze what already happened in the past. Thus, all current hurricane estimation methods are based on historical records of typhoon tracks and intensities. The typical representations of these compilations are the alleged “best track” records, which are stored, maintained and annually updated by several meteorological agencies, such as the global dataset provided by the United States Navy’s Joint Typhoon Warning Center (JTWC) or National Oceanic and Atmospheric Administration’s (NOAA’s) Tropical Prediction Center (TPC) and the local one from the Regional Specialized Meteorological Center (RSMC) operated by the Japan Meteorological Agency (JMA) (Emanuel et al. 2006).

For each reported hurricane, the catalogs generally give some typhoon-related information such as the storm center position in geodetic coordinate (i.e. latitude and longitude) together with intensity estimation (i.e. maximum sustained wind speed and/or central pressure) at six-hour intervals along hurricane track since its initiation (Darling 1991; Jarvinen et al. 1984). These data sets provide a crucial reference in understanding typhoons occurred previously, from which proper risk assessment techniques can be initiated and evolved.

2.3 Data scarcity issue

Typhoon estimations has developed in great demand for reliable risk-based technical evaluation, which is rising along with the increasing in exposure to stronger, more often, rapidly changing and less predictable storms (Peter J. Vickery et al. 2009). Because existing approaches directly base on available observed data (Emanuel et al. 2006), the most crucial limitation relates to the small sample size because hurricanes are both relatively infrequent and small in terms of the length of coastlines affected by these typhoons each year. When coupled with the often low-quality data sets, these techniques can lead to very unreliable evaluations of hurricane frequencies and intensities along the coast. Therefore, it is difficult to derive accurate key parameter of the strongest typhoons, on which risk analysis and design of coastal defense structures must be relied (Hallegatte 2007). In some particular places (e.g. New England in the United States), although the locations have been hardly stricken by hurricane, the possible consequences of a land falling typhoons are massive due to current densely populated urban areas, great economic values of properties and high insurance levels. However, due to the shortness of reported hurricane compilation, there is no trustful estimate available at the moment.

In Vietnam, storm risk study is especially problematic and preliminary research usually faces numerous difficulties. Generally, there is not any complete database on natural hazards, particularly typhoon, and a systematic method, tool or software to store, maintain and analyze this record (Oanh et al. 2011). Observations have been measured, stored and assessed locally, at provincial level. This collection and management methodology leads to an inconsistent and normally non-electrically national compilation. Moreover, the potential problem with sole reliance on observed hurricanes becomes more serious because of budget constraints, lack of suitable techniques, use of observing equipment that produces little reliable data, and also, historically, the aftermath of war in the country from 1945 to 1975. While data sets of typhoon tracks and intensities for more than 150 years are available for many other regions (e.g. North and South Atlantic, East Pacific, North Indian), hurricanes in the East Sea - the ocean region that has directly effects on Vietnam, have only been monitored since the end of World War II by RMSC - a foreign organization. Because local near shore measurements are not presented, typhoon risk assessment in Vietnam suffers a lot from the data scarcity issue.

Therefore, there is a rising demand for advanced techniques that can compensate for the lack of reliable hurricane observations, in order to step up classical hurricane estimation methods and upgrade current risk assessment and management.

3 Scope

Taking into account the above-mentioned situation, the main objective of this research is to develop a suitable method for the simulation of hurricanes on the basis of the available historical record. Vietnam is chosen as a typical case study.
4 Relevance (Scientific and Societal)

Among various typhoon effects, extremely powerful winds and damaging storm surges are two major
destructive causes of most human and financial losses. Thus, hurricane risk can be calculated as follow:

\[ R_{\text{hurricane}} = R_{\text{wind}} + R_{\text{surge}} \]

where \( R \) = the risk associated with the loss due to a threat, which is specified in the superscripts of each term.

Typhoons are divided into several groups according to their intensities (i.e. wind speed) by using a ranking
system. Consequently, one can compute those component risks (i.e. wind and surge) as the sum of the risks for each
different group. For instance, when using Saffir-Simpson scale, which classifies hurricanes into five categories, the
below formulae are applicable:

\[ R_{\text{wind}} = \sum_{i=1}^{5} P_i C_{i,\text{wind}} \]
\[ R_{\text{surge}} = \sum_{i=1}^{5} P_i C_{i,\text{surge}} \]

where \( P_i \) = the probability that a category \( i \) typhoon will occur in any given year; and \( C_i \) = the cost of the loss
if such hurricane occurs due to the impact mentioned in the superscript.

At any location, the risk assessment can be done using the simulation results and some other tools. First, the
large set of modeled typhoons is spitted into five subsets corresponding to different hurricane categories using
Saffir-Simpson scale. The rate of occurrence (i.e. \( P_i \)) is determined directly by counting the number of synthetic
tracks in each subset that pass current location. Wind damage (i.e. \( C_i^{\text{wind}} \)) is the losses due to high wind. It is the sum
of the values of effected properties (if totally destroyed) or portion of those values (in case of partially damaged
properties). When couple with a storm surge model, one can calculate the wind-induced surge based on typhoon
statistics derived from empirical track model. Afterwards, that resulting value is put into a coastal inundation model
to estimate losses caused by storm surge (i.e. \( C_i^{\text{surge}} \)).

5 Research approach

In this study, the empirical track model is chosen as the theoretical framework because of its potential
advantages over other techniques. The track of a typhoon is modeled, starting with its initial point and ending with
its landfall location or point of final dissipation over the sea. Using this approach, a user can compute 6-h changes in
hurricane heading, translation speed, and wind speed along this track as linear functions of previous values of those
parameters as well as typhoon center location and Sea Surface Temperature (SST). Thus, a large database of
synthetic tracks is generated that is based on a limited observed track compilation and a local climatological variable
(i.e. SST). This method is validated through comparisons between the hurricane statistics derived from the historical
data and the simulated ones over the whole South China Sea region.

The above methodology is validated through comparisons between historical and modeled statistics, which are
obtained from a 10,000-year simulation over the entire South China Sea - the ocean region that has directly
effects on Vietnam. Because the evaluation is given within the whole region, all typhoons are taken into account,
even if they end at the ocean or only pass through the research area. This is an improvement over the research by
Vickery et al. (2000). In that pioneering study, only hurricanes that enter the sub-regions around certain Points Of
Interest (POIs) are taken into account. Because those POIs are normally situated at the coastline, typhoons that do
not make landfall were ignored, although they are still very important for various sectors. The results show an
acceptable accuracy in both qualitative and quantitative evaluation.

Finally, the application of this method to risk assessments is proposed.
6 References


