Wind Damages and Prospects for Accelerated Wind Damage Reduction in Japan and in the United States

by

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ABSTRACT

Natural disasters have lead to tremendous losses of life and property in Japan and in the United States. Economic and societal impacts of such events exhibit similar trends in both the countries. Comparative studies of these trends and lessons learned from such impacts seem to have a potential to provide insights on activities to be undertaken to accelerate reduction in damages due to wind and other natural disasters in both the countries. This paper presents representative results of the preliminary phase of a comparative study of the above issues carried out by the authors. The presented results include comparisons of fatalities and property damage and data related to impacts of wind and other natural disasters in Japan and in the United States. Overall, the data collected over the past half century show a significant decrease in the number of fatalities in both the countries, despite of the population growth. However, it is noted that over the same period the level of property damage has grown to an unacceptable level. It is pointed out that in order to reverse this trend coordinated national efforts are desirable in both the countries. Examples of recent initiatives undertaken in Japan and in the U.S. to address this issue are briefly described.

KEYWORDS: wind disasters, fatalities, property loses, natural disaster mitigation

1.0 INTRODUCTION

Natural hazards strike many parts of the world. Recent tsunami tragedy in Indian Ocean basin is a grim reminder about potentially catastrophic impacts of nature's furry. Averaged over time assessments indicate that the highest level of loss of life and property damage is due to natural hazards that are associated with severe weather (floods, hurricanes, tornados, and typhoons) and motion of the earth's crust (earthquakes, tsunamis and volcanoes). Once a natural hazard occurs, it may take a heavy toll on human lives, economy and social fabric. Many catastrophic damages due to natural disasters have taken place in highly populated urban centers and regions in close proximity or along coastal areas. Composite plots of tracks of typhoons in Japan and hurricanes in the United States are clear evidence of this observation. In each country, losses due to significant natural disasters extend far beyond regions directly impacted by a given natural disaster event. In addition to loss of life, injuries and property damage, cumulative losses include indirect economic and societal effects on regional and (at times) on national scales.

Economic and societal impacts of natural disasters in Japan and in the United States exhibit similar trends. Comparative studies of these trends and lessons learned from impacts seem to have a potential to provide insights on activities to be undertaken to accelerate reduction in damages due to wind and other natural disasters in both the countries.

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This paper presents representative results of the preliminary phase of a comparative study undertaken by the authors. The presented data include comparisons of fatalities and property damage, and data related to impacts of wind and other natural disasters in Japan and in the United States. Overall, the data collected over the past half century show a significant decrease in the number of fatalities in both the countries, despite of the population growth. However, it is noted that over the same period the level of property damage has grown to an unacceptable level. Examples of recent initiatives undertaken in Japan and in the U.S. to address this issue are briefly described.

2.0 FATALITIES

Protection of life is given the highest level of priority in development of countermeasures against windstorms and other natural and technological (man-made) disasters. The effectiveness of this strategy in Japan and in the U.S. is evident in Figures 1 and 2, where the number of fatalities per annum, caused by wind phenomena, is plotted. Figure 1 shows the number of fatalities due to typhoons reported by Japan Meteorological Agency [1,2] and population of Japan for the past 55 years (1945 to 2000). As shown in the figure, the maximum number of fatalities exceeded 5000 and it occurred in 1959, as a result of a passage of Isewan-typhoon. The second largest loss of life was 4000 fatalities in 1945, caused by Makurazaki-typhoon. Figure 2 presents a comparison of fatalities due to hurricane landfalls in the U.S. and the U.S. population, [3-5].

The data in Figures 1 and 2 exhibit similar trends. In particular, a decrease in the number of annual fatalities in both the countries can be seen, despite of the population growth. This very encouraging trend is attributed to a number of factors. It is postulated that in the largest measure it is a direct consequence of high priority assigned to protection of human life in extreme wind events and societal support of efforts by policymakers and national as well as local authorities to enforce this priority. At the implementation level, the decrease in fatalities can be attributed to a number of areas: improved weather forecasting, various mitigation measures, better warning systems, population evacuations, public awareness, and others. The same or even greater level of determination will be required to reverse ever increasing property losses due to extreme winds and other natural disasters. This issue is addressed next.

3.0 HAZARD DISTRIBUTION OF PROPERTY LOSSES

Development and implementation of effective measures to mitigate impacts of extreme winds and other natural hazards are long-term undertakings that require setting appropriate processes at a policymaking level. Impact of decisions taken during planning phases and costs of implementation of such activities are substantial and properly mapped information on the addressed hazards is needed to balance cost and other competing factors. One of the most crucial parameters is a breakdown of losses according to hazard categories: wind storm, earthquake, flood, and others. This seemingly simple analysis however does not provide definite answers. This is illustrated in Figures 3 and 4, where percentage contributions of property losses due to various hazards, respectively in Japan and in the U.S., are compared for different averaging periods.

The displayed time sensitivity of the loss breakdown according to hazard type is similar in Japan and in the U.S. However, the overall hazard participation in the property losses differs in the two countries. As can be seen in Figures 3 and 4, the prevailing losses in Japan are due to earthquakes, while in the U.S. they are primarily caused by windstorms. Regarding the percentage share by wind-induced losses, averaged over 5 and 50 years, in

Japan they are respectively 36% and 22%, while in the U.S. they range from 89% (5-year average) through 69% (50-year average).

4.0 SPATIAL DISTRIBUTION OF WIND HAZARDS

The (U.S.-Japan) difference in spatial distribution of wind hazards is illustrated in Figures 5 and 6. Figure 5 [1] shows a 10-year composite of typhoon tracks over Japan. As can be seen, the tracks extend all over Japan. This means that the whole population and property all over Japan are vulnerable to typhoon impacts. Spatial vulnerability to these impacts however varies and it is quantified in wind provisions of Japanese design standards. Figure 6 [6] shows hurricane tracks of concern in the U.S. The area of concern for nearly all the tracks is limited to Florida and south-east Atlantic and Mexican Gulf coastlines. Population of many of these regions is high and growing at a high rate. Thus impacts of hurricane landfalls in these regions have high potential for inflicting major losses. This is in contrast to Japan, where regions of elevated risks to typhoon damages extend beyond strictly-coastline areas, due to Japan's geography (spread over many islands) and the overall relatively high population density.

In passing, it should be mentioned that in view of a localized nature of tornado impacts (frequently in regions of low population) this hazard, although of serious concern, is not addressed in this paper.

5.0 TRENDS IN PROPERTY LOSSES

Figures 7 and 8 depict evolution (over time) of property losses in Japan and in the U.S. Figure 7 [7, 8] shows insured property loss due to major typhoons and floods in Japan. As can be seen, the largest insured losses occurred in 1991, due to typhoon denoted (in the Japanese typhoon listing) as Number 19th. The cumulative large losses due to strong winds are the result of (varying in magnitude) damages to houses, aggregated over large areas [8]. In some instances a strong wind event covered a significant portion of Japan's territory. In view of this observation, the Japanese Non-life Insurance Association revised its treatment of wind hazard insurance policies [9]. In recent years, windstorm losses were dominated by damages to attendant parts of buildings and structures. These components are not required to be in compliance with the structural design standard [10]. Finally, it should be mentioned that some of the growth (over the years) in the insured disaster losses might be attributed to increased participation of homeowners in insurance programs covering natural hazards.

Figure 8 documents the 50-year growth in the total losses due to natural disasters in the U.S. [5]. A comparison of Figures 7 and 8 shows a similar trend - a dramatic increase in the losses over the past decade – in both the countries. It should be noted that the large value of losses for 1992, displayed in Figure 8, is due to landfall of Hurricane Andrew, in southern Florida. A major contributing factor to these losses was extensive damage inflicted to single-family dwellings and manufactured homes - majority not in compliance with existing design standards and codes of practice. Extensive post-Andrew efforts by the code officials [11] led to development of stricter codes and regulatory mechanisms for enforcement of such codes. The effectiveness of these efforts has been tested in full scale during the 2004 hurricane season. Preliminary reports of 2004 damage investigations indicate that the hurricane resistance of buildings and structures constructed or retrofitted in compliance with post-Andrew codes was overall satisfactory. Further analysis is needed to quantify these observations.

6.0 PREDICTION OF LOSSES

The ability to predict losses due to natural disasters can serve as an important aid in development of strategy for loss reduction. Application of innovative tools of analysis can significantly enhance such an effort. An example of such a study is presented in Figures 9 and 10, where application of fractal analysis to predict future losses based on the data record covering past years [12,13], is illustrated. By appropriate processing, the fractal dimension of the data set can be determined. This dimension, denoted as D and determined for various disasters in Japan and in the U.S., is shown in Figures 9 and 10, respectively. Assuming self-similarity, loss predictions for long return periods can be made using the fractal dimension (or other measures) calculated from data sets covering shorter time periods.

7.0 INITIATIVES TO REDUCE WIND LOSSES IN JAPAN AND IN THE U.S.

7.1 Wind Effects Center in Japan

The 21st Century Center of Excellence for Wind Effects on Buildings and Urban Environment (COE) was established in 2003 by the Ministry of Education, Culture, Sports, Science and Technology [14]. The core of COE is the Wind Engineering Research Center (WERC) housed at Tokyo Polytechnic University. Activities of WERC are focused on research and education on wind effects on buildings and urban environment in various areas concerning air flow, and urban and architectural problems associated with wind environment. Areas of interest include wind hazard, ventilation issues and diffusion of air contaminants. The COE activities are carried out utilizing personnel and laboratory as well as field testing infrastructure integrated within WERC. Dissemination of findings of research and development of wind hazard mitigation measures is to be accomplished through establishment of the Wind Engineering Information Center. Outreach beyond Japan - to countries of the Asia-Pacific region - is also a part of the COE mission. This charge is to be addressed by the APEC (Asia-Pacific Economic Cooperation) Wind Hazard Center.

The main thrusts of the COE activities are grouped in two categories:

I. Educational Plan
II. Research Projects

The scope of these categories is briefly described below.

I. <u>Educational Plan [15]</u>

The APEC Wind Hazard Center and the Technical Information Room for Wind Engineering will be set up at WERC. It is planed to use these resources to carry out education and delivery of international information focused on wind engineering. The objectives of these activities are as follows:

A. Prepare education materials for wind effects on buildings and urban environment, and infrastructure for utilization of information technology;
B. Implement on-job-training for research and encourage students in wind engineering to excel in their professional practice and in societal contributions;
C. Encourage engineering practice and research in APEC countries, and transfer wind hazard mitigation measures appropriate to needs of a particular country;
D. Deliver courses, promote continuing education and seek feedback on societal impacts of wind engineering;
E. Implement international joint research and host international seminars in order to promote international exchange of technical information and to provide forum for interaction among researchers of international prominence.

<u>II. Research Projects [16]</u>

The COE research activities comprise of the following three projects:

A. Wind Hazards Mitigation
   Wind resistant design methods, health monitoring systems, and urban wind disaster mitigation system.

B. Design Methods of Natural / Cross Ventilation
   Sustainable design methods of outdoor / indoor air environment, reduction in energy consumption.

C. Air Pollution and Its Assessment System
   Air pollution inside building/sick house, discharged gas in urban area.

7.2 National Wind Program in the U.S.

7.2.1 Proposal to Establish National Program to Reduce Wind Damages

The proposal to establish the National Wind Hazards Reduction Program (NWHRP) was developed by an ad hoc Committee on Wind Engineering Research Needs (chaired by B. Bienkiewicz) and presented to U.S. wind engineering community in a report entitled "Wind Engineering Research and Outreach Plan to Reduce Losses due to Wind Hazards" [17]. It was postulated that such a program would lead to significant reduction in vulnerability to wind hazards in the United States within the next decade.

The concept of NWHRP builds on lessons learned from the 25-year experience with the National Earthquake Hazards Reduction Program (NEHRP) and is an adaptation of the action plan developed for NEHRP by earthquake engineering community. It comprises of the following four components:

A. Understanding of Wind Hazards
   Development of knowledge on severe winds; quantification of the attendant wind loading on buildings, structures and infrastructure; and mapping of wind hazards.

B. Assessment of Impact of Wind Hazards
   Assessment of performance of buildings, structures and infrastructure; development of frameworks and tools for simulation and computational modeling; and development of tools for system level modeling and loss assessment.

C. Reduction of Impact of Wind Hazards
   Development of retrofit measures for existing buildings, structures and infrastructure; development of innovative wind-resistant technologies for buildings, structures and infrastructure; and development of land measures and cost effective construction practices consistent with site-specific wind hazards.

D. Enhancement of Community Resilience, Education and Outreach
   Enhancement of community resilience to wind hazards; effective transfer to professionals of research findings and technology via outreach efforts developed for each component of the NWHRP; and development of effective educational programs and public outreach activities.

Efforts specified for each of these components consist of research and outreach tasks. The research tasks address the science and engineering as well as societal approaches necessary for better risk management practices desirable to prevent losses caused by wind hazards. The outreach tasks are focused on transfer of the research findings and the developed technology to practice.

In formulation of the NWHRP attempts were made to develop a dynamic program that would allow for timely use of outcomes of ongoing (in the United States and elsewhere) related research and outreach efforts addressing mitigation of losses due to wind and other natural hazards. Particular attention was given to activities in the area of earthquake engineering, carried out within and beyond the framework of NEHRP. These activities were carefully examined to avoid duplication of efforts delineated in the scope of work proposed for NWHRP.

Recent revolutionary developments in information technology (including sensors, data collection, transfer, processing and visualization, experimental and computational simulation, high-end computing and networking infrastructure) have a potential to lead to unprecedented breakthroughs in our efforts to reduce property losses and human suffering due to wind hazards. Seizing the above opportunities will require federal investment to upgrade the existing and develop new research and outreach infrastructure and human resources.

7.2.2 Congressional Activities to Establish National Program

The proposal for establishment of NWHRP was formally presented to U.S. House of Representatives during a Congressional hearing held in February 2004, testimony by B. Bienkiewicz [18]. This hearing was one of several Congressional hearings and briefings on wind hazards, impacts and mitigation, held over the past five years. During that time a couple of versions of a Congressional Bill calling for establishment of a national program focused on reduction of wind losses were introduced and debated. The concept for the program proposed in [17] was incorporated in the final version of the Bill. This Bill was passed by U.S. House in March 2004 and it was subsequently appended to a larger Bill (that included also renewal of the National Earthquake Hazards Reduction Program), which was passed in the U.S. Senate and signed into law in October 2004. The wind hazards reduction program is denoted in the Congressional Act as the National Windstorm Impact Reduction Program (NWIRP). An implementation plan for the program is expected to be developed in 2005. It is anticipated that the program will be activated in 2006.

The program comprises of the following three primary mitigation components:

I. Improved Understanding of Windstorms
II. Windstorm Impact Assessment
III. Windstorm Impact Reduction

The scope of each component, as delineated in the Congressional Act, includes the following activities:

I. Improved Understanding of Windstorms

Activities to enhance the understanding of windstorms shall include research to improve knowledge of and data collection on the impact of severe wind on buildings, structures, and infrastructure.

II. Windstorm Impact Assessment

A. Development of mechanisms for collecting and inventorying information on the performance of buildings, structures, and infrastructure in windstorms and improved collection of pertinent information from sources, including the design and construction industry, insurance companies, and building officials;

B. Research, development, and technology transfer to improve loss estimation and risk assessment systems;

C. Research, development, and technology transfer to improve simulation and computational modeling of windstorm impacts.

III. Windstorm Impact Reduction

A. Development of improved outreach and implementation mechanisms to translate existing information and research findings into cost effective and affordable practices for design and construction professionals, and State and local officials;

B. Development of cost-effective and affordable windstorm-resistant systems, structures, and materials for use in new construction and retrofit of existing construction;

C. Outreach and information dissemination related to cost-effective and affordable construction techniques, loss estimation and risk assessment methodologies, and other pertinent information regarding windstorm phenomena to Federal, State, and local officials, the construction industry, and the general public.

To the extent practicable research activities shall be peer-reviewed and the program components shall be designed to be complementary to, and avoid duplication of, other public and private hazard reduction efforts.

It is expected that funding to be ultimately appropriated for program will be at the level stipulated by the Congressional Act (H.R.2608, Sec. 204) and the Public Law (108-360). As the program is implemented and expanded over the years, its societal and economic impacts are expected to be clearly evident from accelerated reductions in fatalities and property losses due to wind hazards in the U.S., and potentially in other countries.

8.0 CONCLUDING REMARKS

As demonstrated in this paper the issue of impacts of natural disasters is of concern in Japan and in the United States. Over the past half century significant reduction in fatalities caused by natural disasters in general and extreme winds in particular has been achieved. Although the percentage contribution of wind events to the overall property damage is different in the both countries, sufficient level of similarity exists with respect to other factors relevant to wind hazards to warrant expanded US-Japan collaboration in the area of wind damage reduction.

In recognition of a significant increase over the past decade in wind-induced property damages, both countries have initiated coordinated efforts to address this issue. Center of Excellence for Wind Effects and Urban Environment has been established in Japan. In the United States, the National Windstorm Impact Reduction Program is being activated.

US-Japan collaboration in the area of wind damage reduction could be incorporated in the framework of the above initiatives or through other existing and/or to be established frameworks. One of options to aid this collaboration could be adaptation of the model developed by the National Earthquake Engineering Reduction Program (and coordinated through mechanisms of the UJNR framework), for U.S.-Japan collaborative research activities geared towards reduction of losses due to significant earthquakes.

9.0 ACKNOWLEDGEMENTS

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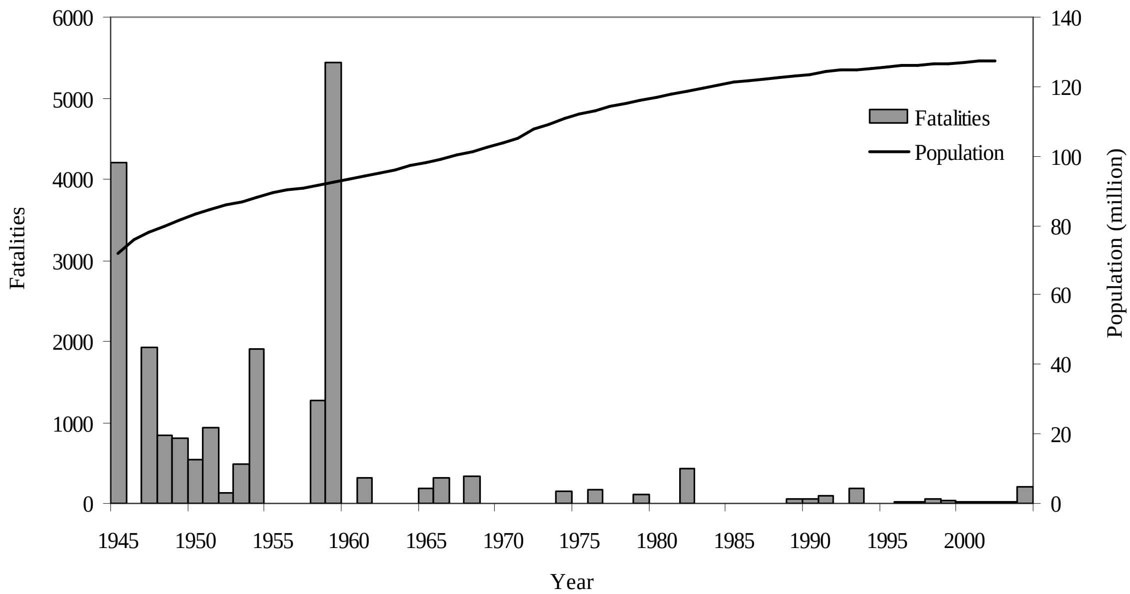

Figure 1: Typhoon disaster fatalities and population of Japan

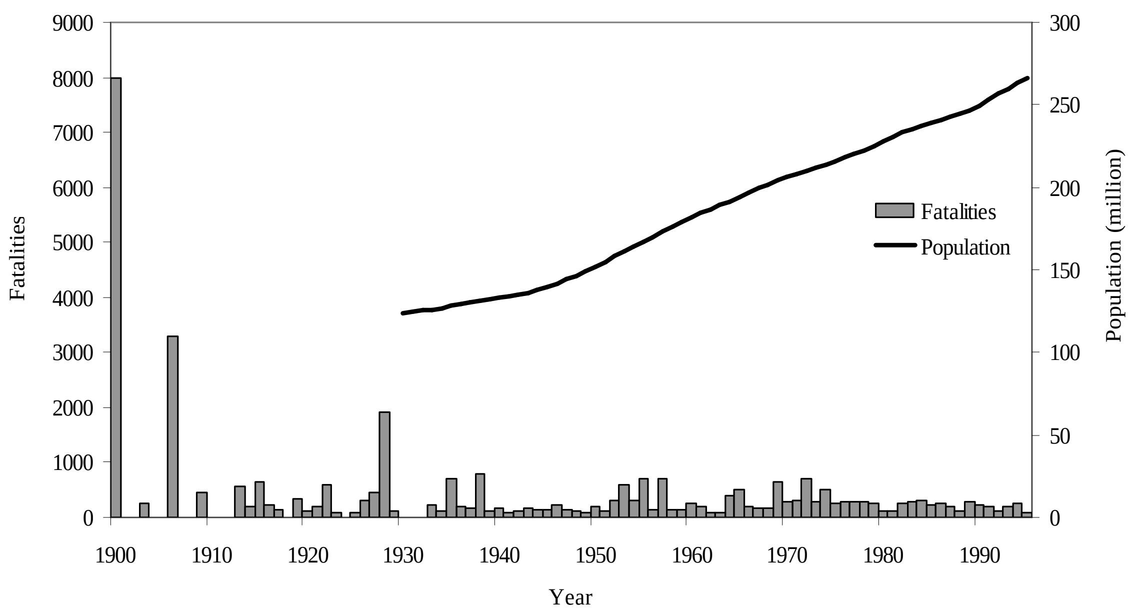

Figure 2: Hurricane disaster fatalities and population of U.S.

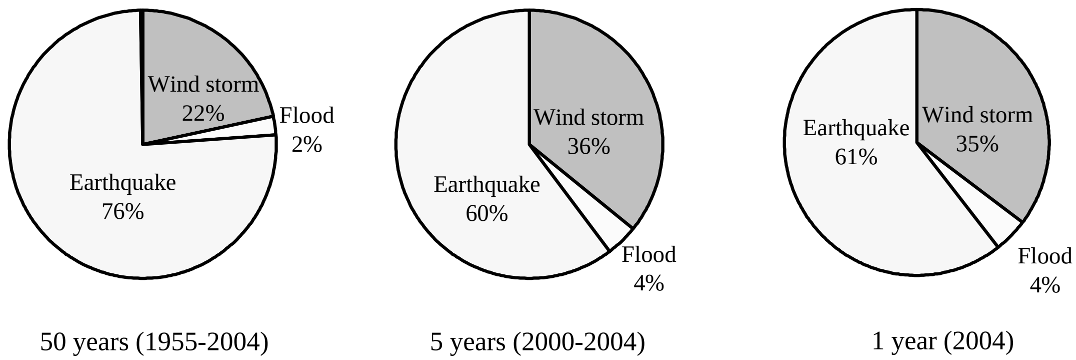

Figure 3: Distribution of losses in Japan

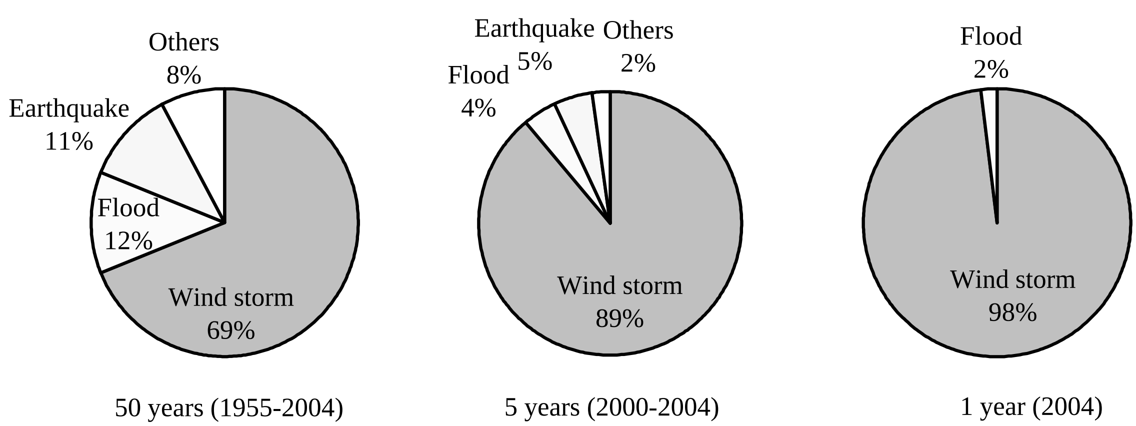

Figure 4: Distribution of losses in the U.S.

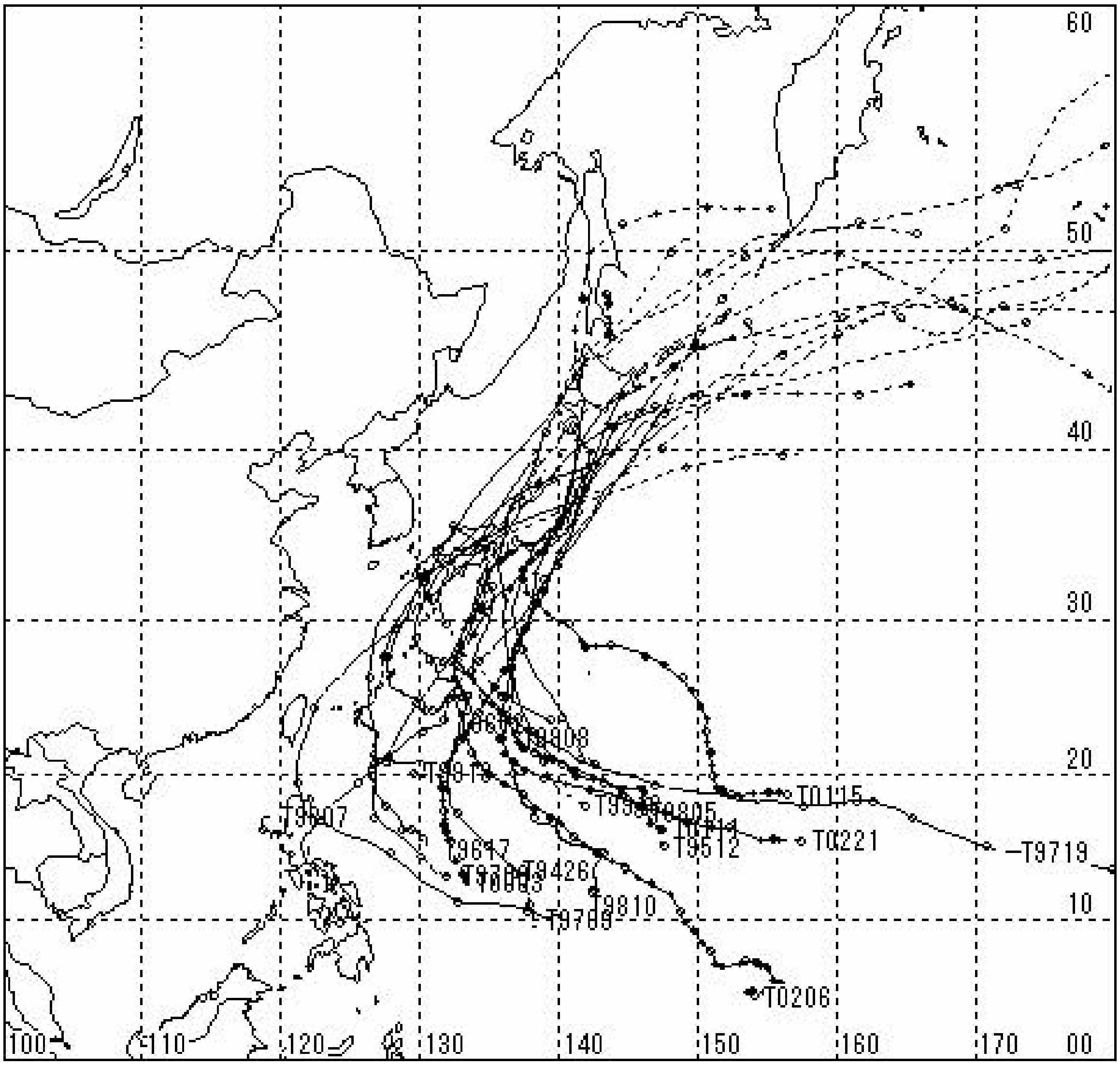

Figure 5: Typhoon tracks over Japan

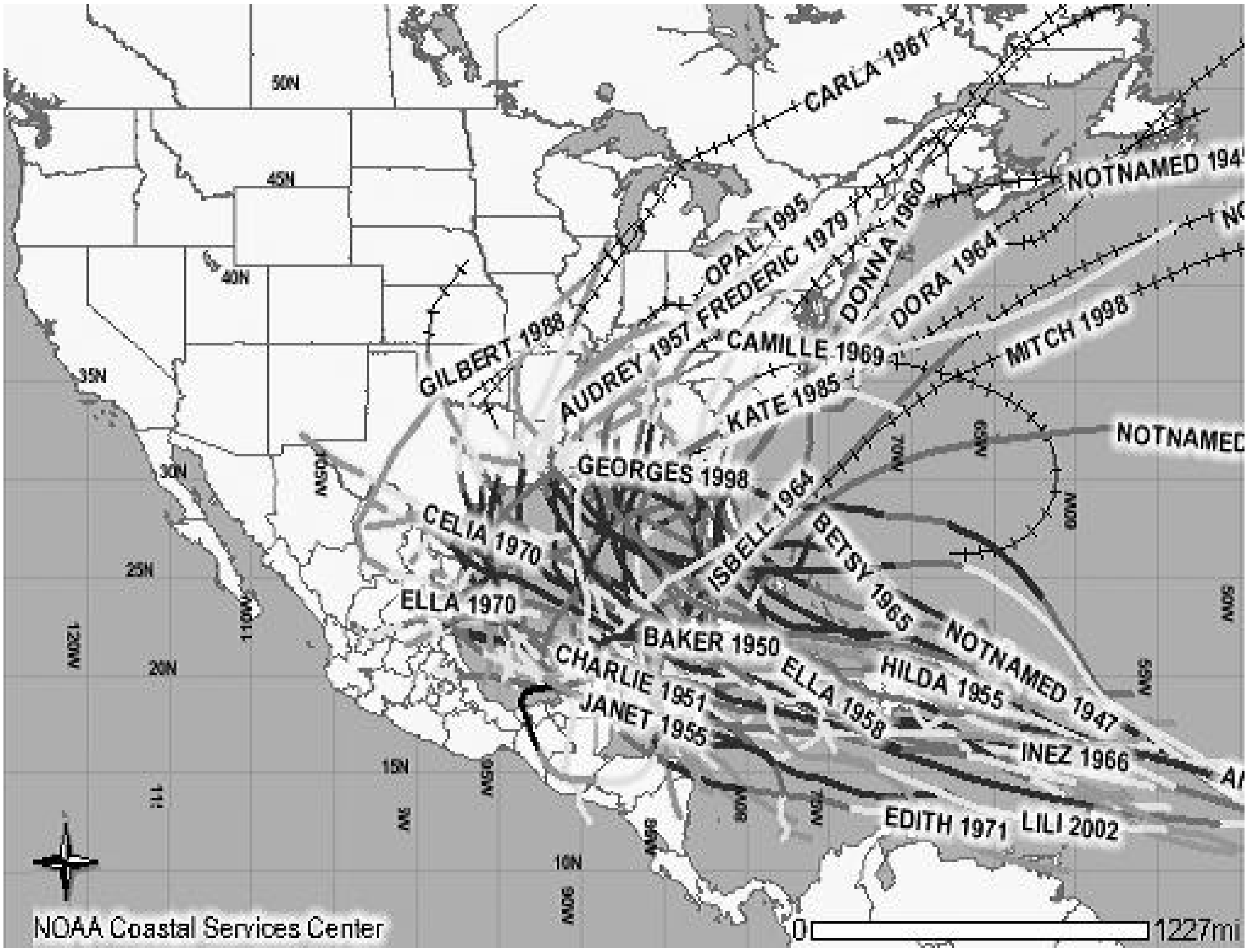

Figure 6: Hurricane tracks over the U.S.

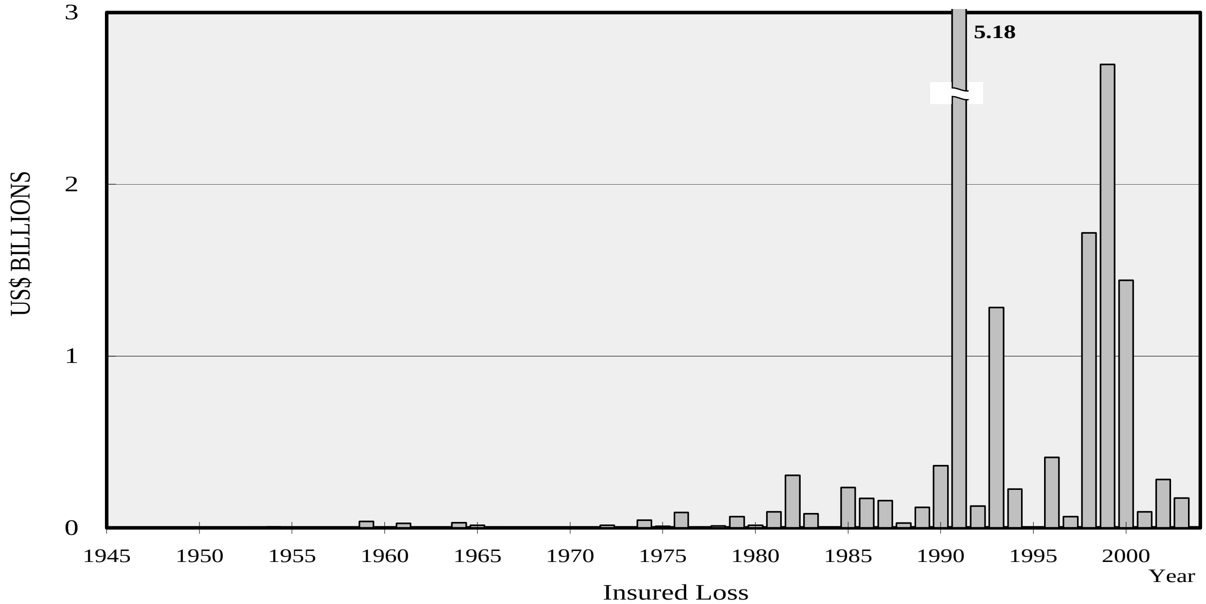

Figure 7: Insured losses from wind storm disasters in Japan

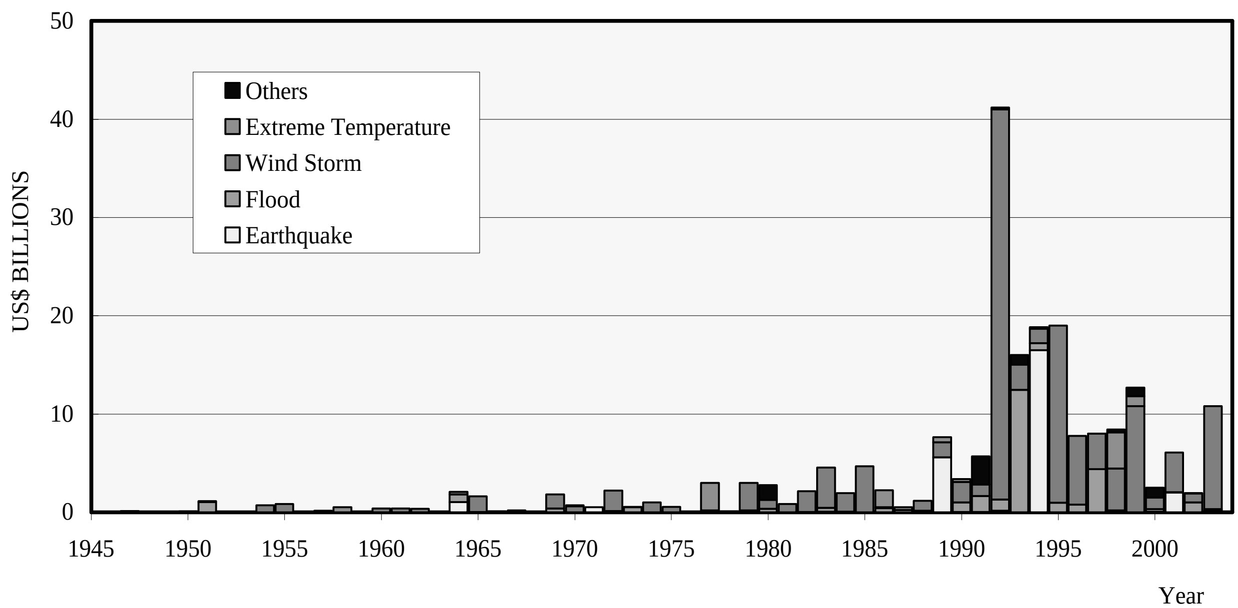

Figure 8: Total losses from natural disasters in the U.S.

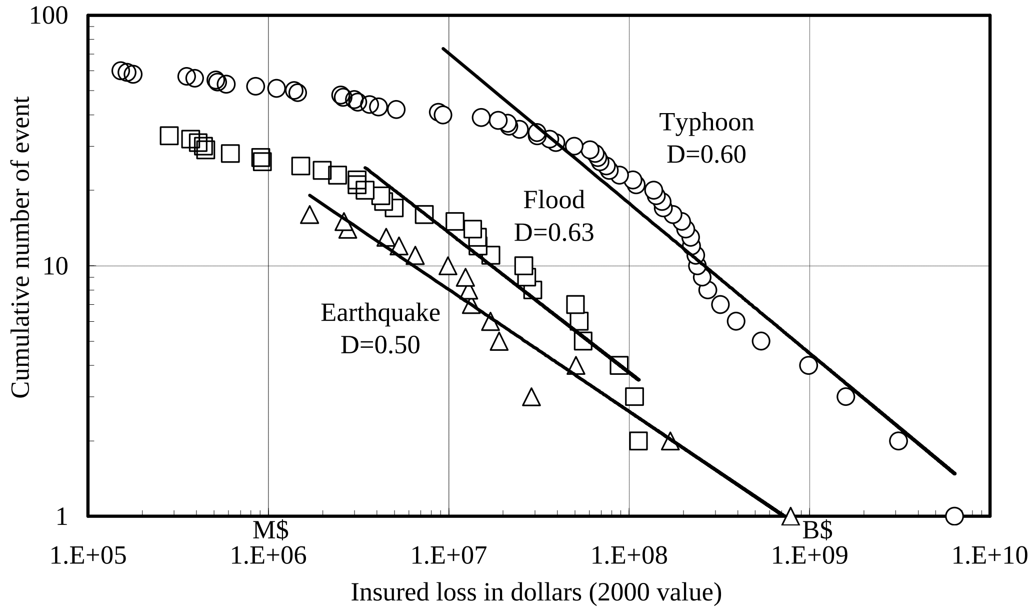

Figure 9: Cumulative frequency of insured losses for 50 years in Japan

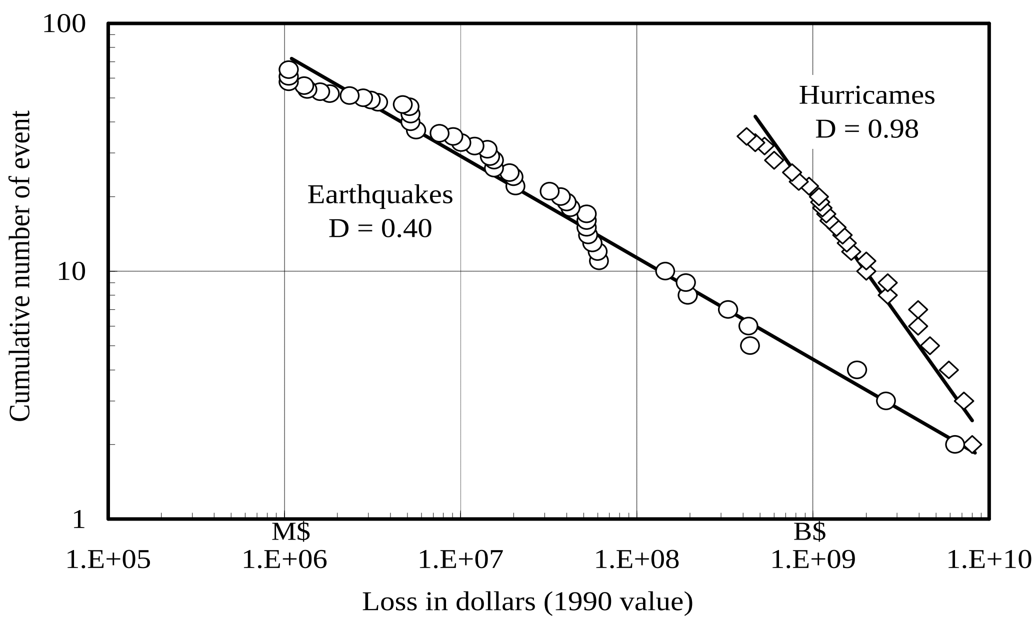

Figure 10: Cumulative frequency of total losses for 100 years in the U.S.