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Three Great Tsunamis: Lisbon (1755), Sumatra–Andaman (2004) and Japan (2011)

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Preface

The idea of doing a SpringerBrief on the "Three Great Tsunamis" emerged while talking with Petra van Steenbergen at the Springer Stall at Taipei on August 9, 2011 during the 8th Annual Convention of the Asia Oceania Geosciences Society (AOGS). I (the first author) was at the Springer Stall in connection with the "Author Meet and Greet" event for the just published "Encyclopedia of Solid Earth Geophysics" edited by me. The Encyclopedia was very well received. During our conversation Petra told me about the SpringerBriefs and how these briefs focus on a topical issue in a simple, easy to be understood by all approach. We had organized a special session during the 8th AOGS Convention dedicated to the scientific work on the Great Mw 9.0 Tohoku earthquake and the resultant tsunami that devastated Fukushima and the nearby regions a few months earlier on March 11, 2011. On December 26, 2004, the mega Sumatra–Andaman earthquake of Mw 9.1 had occurred, which had claimed an estimated 2,30,000 human lives. I was deeply involved with setting up of India's Tsunami Warning System, which had become operational in September 2007. I was also invited to a symposium in Portugal to revisit the November 1, 1755 great Lisbon earthquake and the resultant tsunami that had claimed close to 1,00,000 human lives and had totally destroyed Lisbon; and the tsunami related developments over the past two and a half centuries. Earlier, I had also listened to a very interesting talk by Prof. Carl Fuchs where he had compared the happenings at Lisbon during 1755 and in east and South–East Asia during the 2004 Mw 9.1 earthquake generated tsunami. I talked with Petra about these three tsunamis. She liked the idea very much and encouraged me to consider writing about the three tsunamis as a SpringerBrief book. I kept toying with the idea of doing a SpringerBrief on the Three Great Tsunamis, however, time was a constrain. I met Petra a few months later during the Fall Meeting of the American Geophysical Union at San Francisco in December 2011, and Petra suggested that I take a co-author to expedite the writing of the book. I discussed about this project with Vineet Gahalaut, a colleague of mine, and he graciously agreed to be a co-author.

With the passage of time the impact of earthquakes and the resultant tsunamis is on an increase. This is in spite of tremendous developments in natural and social sciences in the past few decades. It is interesting to note that at the time

of writing the 'Preface', just 12 years of the twenty-first century have been completed. However, in these 12 years, more human lives are lost due to earthquakes and the resultant tsunamis than the entire twentieth century. Since the occurrence of the Lisbon tsunami in 1755, a lot has happened. The Lisbon earthquake is credited to be beginning of the science of Seismology. At that time, there was a great debate whether the earthquake was an act of God or a natural phenomenon. The questionnaire sent then to collect the information about the earthquake has been a great source of information and research even today. By the time of the 2004 Sumatra–Andaman tsunami, the science of locating earthquakes, and issuing tsunami warnings was well developed. However, tsunamis in the Indian Ocean had been very rare. In the twentieth century, only three tsunamis, not very large ones, had occurred in the Indian Ocean. The huge number of lives lost was partly due to ignorance: many people walked into the bare ocean floor as the tsunami trough had emptied the near coast sea floor. Moreover, December 26, 2004, being a Sunday and the tsunami occurred in the morning hours and there were many taking a morning walk near the sea shore and got killed. Another reason of high number of lives lost and the immense loss of property was the flouting of the laws which prohibit commercial activity within 500 m from the high tide line in most countries. The situation was totally different for the March 11, 2011 Tohoku earthquake of Mw 9.0. Japan is the country which is most frequented tsunamis. However, the magnitude of the 11 March earthquake far exceeded the estimated size of earthquakes in that region, and the tsunami defense measures were falling short of the requirements for the occasion. It must, however, be mentioned that but for the scientific, technological, and administrative measures taken in Japan, the loss of human lives and property would have been much more.

It is hoped that this book would provide an interesting reading to many desirous to learn about tsunamis, and developing a tsunami resilient society.

We would like to thank Petra van Steenbergen for support to this project of writing. Several of our colleagues at the National Disaster Management Authority (NDMA), National Geophysical Research Institute (NGRI) and Indian National Centre for Ocean Information and Services (INCOIS) helped in compiling the text for this book. Springer needs to be thanked for timely and beautiful production of this book.

Harsh K. Gupta
Vineet K. Gahalaut

Contents

Introduction

Tsunamis are primarily caused by earthquakes. Under favorable geological conditions, when a large earthquake occurs below the sea bed and the resultant rupture causes a vertical displacement of the ocean bed, the entire column of water above it is displaced, causing a tsunami. In the ocean, tsunamis do not reach great heights but can travel at velocities of up to 1,000 km/h. As a tsunami reaches shallow sea depths, there is a decrease in its velocity and an increase in its height. Tsunamis are known to have reached heights of several tens of meters and inundate several kilometres inland from the shore. Tsunamis can also be caused by displacement of substantial amounts of water by landslides, volcanic eruptions, glacier calving, and rarely by meteorite impacts and nuclear tests in the ocean.

In this SpringerBrief, the causes of tsunamis, their intensity and magnitude scales, global distribution and a list of major tsunamis, are provided. The three great tsunamis of 1755, 2004, and 2011 are presented in detail. The 1755 tsunami caused by the Lisbon earthquake, now estimated to range from Mw 8.5 to 9.0, was the most damaging tsunami ever in the Atlantic Ocean. It claimed an estimated 1,00,000 human lives and caused wide-spread damage. The 2004 Sumatra–Andaman Mw 9.1 earthquake and the resultant tsunami were the deadliest ever to hit the globe, claiming over 2,30,000 human lives and causing wide-spread financial losses in several South and South–East Asian countries. The 2011 Mw 9.0 Tohoku-Oki earthquake and the resultant tsunami were a surprise to the seismologists in Japan and around the globe. The height of the tsunami far exceeded the estimated heights. It claimed about 20,000 human lives. The tsunami also caused nuclear accidents. This earthquake has given rise to a global debate on how to estimate the maximum size of an earthquake in a given region and the safety of nuclear power plants in coastal regions. This Brief also includes a description of key components of tsunami warning centers, progress in deploying tsunami watch and warning facilities globally, tsunami advisories and their communication, and the way forward.

Chapter 1
Fundamentals of Tsunamis

Abstract This chapter deals with the causes, characteristics, occurrences, propagation, intensity and magnitude scales etc. of tsunamis. A worldwide list of major tsunamis is provided.

1.1 Introduction

The word tsunami (pronounced as tsoo-nah-mee) is a Japanese word that means *harbor wave (tsunami)*. This is a word that has been coined by Japanese fishermen. They would return from the sea to find that their villages had been destroyed by large waves. While at sea, they did not see or experience waves large enough to wash away a village. There are very few other languages that have an equivalent native word for tsunami. In the Tamil language (Tamilnadu, an east coast province of India), the word is *aazhi peralai (destruction big-waves)*. In the Acehnese language (in Aceh, Sumatra, Indonesia), it is *ië beuna* or *alôn buluël*. In the Defayan and Sigulai languages, spoken on Simeulue Island, off the western coast of Sumatra in Indonesia, the word is *smong and emong*, respectively.

Although several instances of historical tsunamis have been reported, based on the identification of paleotsunami deposits and their dating, the most specific historical record of a tsunami is from the Malian Gulf (a gulf of the Aegean Sea). In the summer of 426 BC, a tsunami hit the Malian Gulf between the northwest tip of Euboea and Lamia. The Greek historian Thucydides described how a series of earthquakes during 431–404 BC occurred causing a tsunami that affected the region. Remarkably, he could correlate the earthquake and the tsunami. The Roman historian Ammianus Marcellinus described a typical sequence of a tsunami, including an incipient earthquake, the sudden retreat of the sea followed by a gigantic wave during the AD 365 tsunami that devastated Alexandria. Japan is the nation with the most recorded tsunamis in the world. The earliest recorded disaster being the AD 684 Kakuho earthquake. The number of significant tsunamis in Japan totals 195 since AD 684, averaging one event every 6.7 years, which is the highest rate of occurrence

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