OTC 18602

Special Session: Offshore Drilling and Development Geohazards: An International Perspective (I or II): Tsunamis Generated by Landslides and Earthquakes—Wave Characteristics and Numerical Modeling for Hazard Assessment in Offshore Geohazards

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This paper was prepared for presentation at the 2007 Offshore Technology Conference held in Houston, Texas, U.S.A., 30 April–3 May 2007.

Abstract

The wave characteristics and hazards related to tsunamis generated by submarine landslides and earthquakes are discussed. Example simulations of the 8100 BP Storegga Slide tsunami, the probable pre-Last Glacial Maximum Hinlopen Slide, potential North Sea Fan and La Palma scenarios, the 1998 Papua New Guinea tsunami, and the 2004 Indian Ocean tsunami are included to illustrate how the source parameters influence tsunami characteristics. For hazard or risk assessment, it is shown how these parameters may be related to probability.

Both the Storegga and the Hinlopen slide most likely generated severe tsunamis. The Storegga Slide tsunami reveals a typical dipole wave structure generated by huge and subcritical landslides of moderate acceleration. For the Hinlopen slide bathymetric effects as well as high speed and huge thickness of the dislodged mass and the rafted blocks probably implied that shorter wave components introducing dispersive and nonlinear effects were more pronounced. The North Sea Fan scenario illustrates tsunamis generated by smaller slides in deeper water. The 2004 Indian Ocean tsunami is used as an example of tsunamis of seismic origin that is initially more similar to a line source with much less radial spread. The latter example is also used to illustrate the importance of the current speed for the wave impact. A possible tsunami originating at La Palma in the Canary Islands and the 1998 Papua New Guinea tsunami are used to illustrate dispersive tsunamis caused by subaerial landslides and combined sources, respectively.

Challenges in numerical modeling are related to the huge dimensions and long run-out distances of the landslides, to interpretation of the lithosphere geometry and rheology as well as coupling to regional geophysical and geological conditions for seismic sources, and to the optimal coupling and application of a diversity of hydrodynamic models for landslide dynamics, tsunami generation, propagation, and run-up of tsunamis in huge and complex domains.

Finally, hazard and risk assessment of tsunamis generated by submarine landslides and earthquakes includes both geotechnical and geological considerations for the probability and the tsunami-genic power of the source as well as tsunami and vulnerability evaluations for determination of the consequences. Landslides or earthquakes generating large-scale tsunamis are rare events, but with the dramatic consequences in mind tsunamis must be considered a high-risk geohazard.

Introduction

Tsunamis are surface waves due to an impulsive perturbation of the sea, having features intermediate between tidal waves and swell waves in the spectrum of gravity water waves. Submarine landslides, in addition to submarine earthquakes, are the principal cause of large tsunamis. The earthquakes can also play an indirect role as the landslide triggering mechanism.

In addition to being a treat to human lives, tsunamis may – as landslides and earthquakes themselves – constitute a threat in terms of direct wave impact or currents to offshore installations including platforms, risers, pipelines, ships, and to coastal installations. Coastal or shallow water structures are more endangered due to higher wave current velocities in these places.

This paper mainly discusses the tsunamis generated by submarine landslides as they may be a result of industrial offshore activities and hence of more concern with respect to responsibility and influence on the third party.

However, comparisons are also made to tsunamis generated by earthquakes or subaerial landslides. This is made to demonstrate the different characteristics of waves generated by different sources, but also because these (often distant) sources might represent another kind of tsunami threat to the offshore industry.

The first part of the paper describes with several example scenarios how landslide and earthquake parameters influence tsunami characteristics. For hazard or risk assessment, these parameters should further be related to probability. The