MITIGATING THE EFFECTS OF TSUNAMIS: WHERE DO WE GO FROM HERE?

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ABSTRACT

During the decade of the IDNDR, significant progress has been made towards more effectively mitigating the tsunami hazard, much of it though the activities of the IOC International Coordination Group for the Tsunami Warning System in the Pacific (ITSU) and its Member States. Worldwide historical tsunami data have been compiled in computer databases with graphical interfaces for more widespread access and to better assess the tsunami hazard in each coastal region. Numerical modelling of tsunamis has matured, and this technology has been transferred to many countries at risk for producing realistic tsunami run-up maps to guide coastal development and emergency planning. Warning systems have better and faster access to high-quality seismic and water level data, better techniques for evaluating tsunamis, and more effective methods for disseminating warnings. Educational materials for both children and adults have been produced in many languages. But with ever-increasing coastal development and population growth, significant challenges remain. Eleven destructive tsunamis have occurred since 1990, causing over 4 000 casualties and significant property damage. When these events are examined, it is possible to identify ways that mitigation efforts have helped, but more often how those efforts need to be expanded and improved in the future.

TSUNAMI PHENOMENON

A tsunami is a series of ocean waves generated by any sudden and large-scale disturbance of the sea or other large body of water. Earthquakes generate most tsunamis, but they can also be generated by landslides and submarine slumps, by volcanic eruptions next to or beneath the sea, and even by meteorite impacts. Recently it has been recognized that some tsunamis that accompany earthquakes are enhanced or may have been produced entirely by landslides or slumps. Tsunamis have occurred in every ocean, but are most common in the Pacific owing to its high level of seismic and volcanic activity. Most often, large tsunamis occur at subduction zones — regions where two of the earth's plates converge and one is diving beneath the other (Figure 1). When great earthquakes take place along these boundaries, the sea-floor over a very large area can be vertically and permanently displaced by as much as several meters. This deformation in turn produces an elevation or depression of the sea surface. In the process of the sea surface coming back to equilibrium, tsunami waves form and propagate away in all directions from the displacement.

Tsunami waves are distinguished from ordinary ocean wind waves by their very long period, high propagation speed, and long wavelength. Tsunami wave periods — the time between one wave crest and the next — range from about 5 to 60 minutes, depending upon the size of the disturbance that generated them The speed a tsunami travels depends upon the depth of the ocean by the simple relationship: speed = square root (acceleration of gravity x water depth). In mid-ocean, tsunamis can travel at speeds of 800 km/hr or more — the speed of a commercial jet aircraft. As a consequence, it takes less than 24 hours for a tsunami to cross the entire Pacific basin (Figure 2). As a tsunami waves near shore, however, they slow down to the speed of the wind waves — a few tens of kilometres per hour. The wavelength of a tsunami, which is simply its speed times its period, also depends upon the ocean depth. In mid-ocean, tsunami wavelengths may be several hundred kilometres, but near shore the same waves can shorten to only a few kilometres in length as they slow down.

The height of a tsunami depends upon several factors. Near the source, the height may be several meters and it mirrors the deformation that has occurred on the ocean floor As it moves away from the source, tsunami wave heights are reduced by the spreading of the wavefronts into ever-larger circles, thus reducing

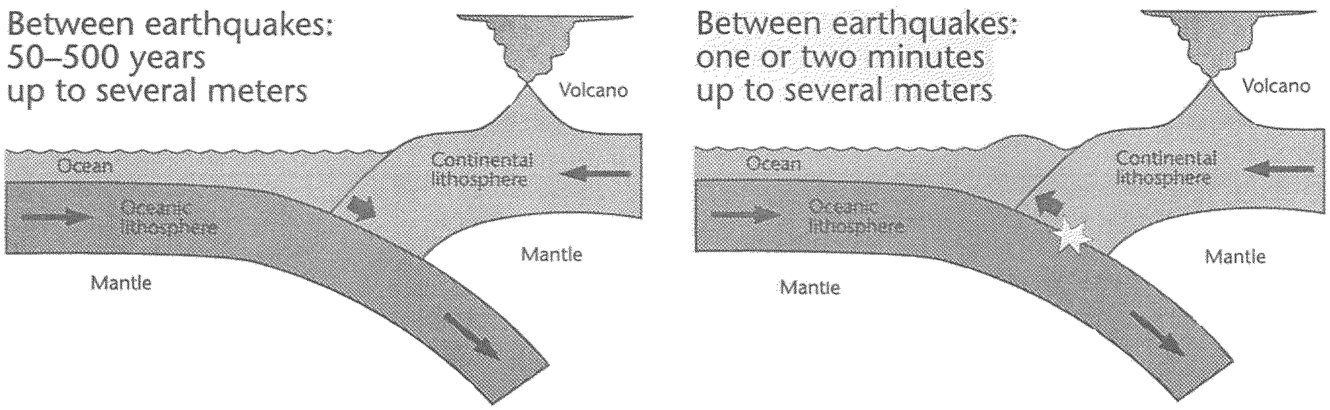

Figure 1. Most major tsunamis are generated at convergent plate boundaries where two plates of the earth's lithosphere are moving towards each other. One plate (typically the oceanic plate) is sliding beneath the other (typically the continental plate) at a rate of a few cm per year. If the contact surface is locked over a long time period, then stresses will build and the continental plate near the boundary can be bent downward by up to several meters. When this boundary slips in a great earthquake, the plate quickly rebounds, pushing up a mound of water several meters high on the ocean surface. Tsunami waves then form and move away in all directions from this mound, the ocean then settles back to a state of equilibrium.

their energy density. Even a great tsunami is often less than a meter high in the deep ocean and is undetectable as it passes beneath ships at sea. Due to its long wavelength, the energy in a tsunami wave extends all the way to the ocean floor. Consequently, as water depth and wavelength decrease when a tsunami approaches shore, its energy becomes increasingly concentrated causing the wave height to grow, sometimes to tens of meters.

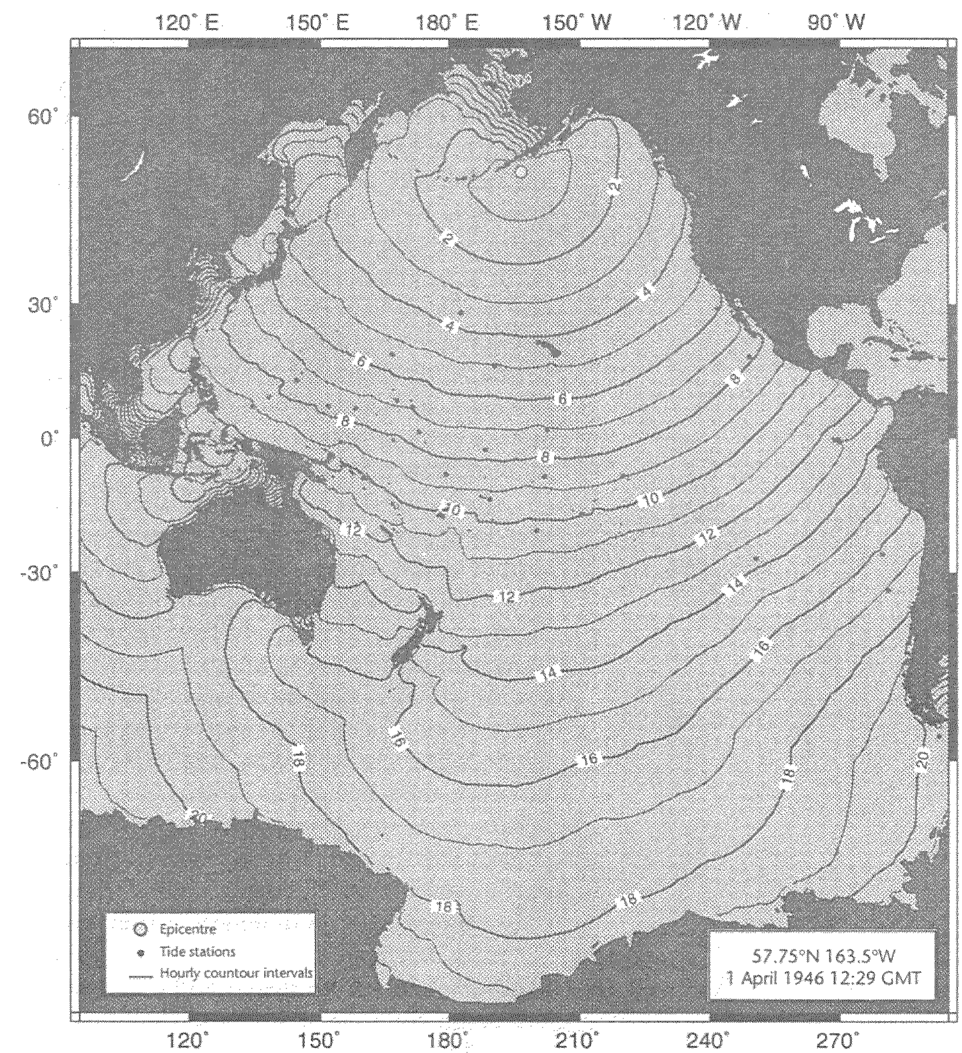

Figure 2. Estimated travel times for the very destructive tsunami generated near Unimak Island, Alaska, on 1 April 1946. The interval between contours is one hour. As illustrated by this case, a tsunami can propagate across the entire Pacific basin in less than a day. This poses a challenge for the warning system since there is only a very limited amount of time available to gather seismic and sea-level data needed for accurate tsunami forecasting, and also to disseminate a warning to all potentially affected coastal communities. Recent advances in communications technology are now being applied to help overcome this problem.