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Tsunamis Within the Eastern Santa Barbara Channel

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Abstract. Several locally generated tsunamis have been reported in Southern California during the past 200 years, yet the hazard from locally generated tsunamis has received considerably little attention. We consider here tsunamis generated by coseismic displacements on the Channel Islands Thrust (CIT) system, as well as waves generated by slope failures along the walls of the Santa Barbara Channel. We find that purely tectonic sources could generate regional tsunamis with $\approx 2m$ runup, whereas combinations of tectonic sources and submarine mass movements could generate local runup as large as $\approx 15m$.

Introduction

Until the identification of the Cascadia subduction zone, the mitigation of locally generated tsunami hazards had received little attention, even for densely populated coastlines in the continental United States. Although historically tsunamis have caused enormous losses farfield, their long travel times allow for early warning. In contrast, locally generated tsunamis may have travel times as short as a few minutes. Furthermore, nearshore tsunamis may be enhanced by coseismic submarine mass failures. For example, the tsunami generated by the $M_w \approx 8.0$ Manzanillo, Mexico earthquake of 1995, hit the coast within $15min$ of the earthquake [*Borrero et al.*, 1995]; photos can be found at http://www.usc.edu/dept/tsunamis. Typical maximum runup values ranged from $2-4m$ – roughly as expected for the induced seafloor deformation. In contrast, the tsunami generated after the 1998 $M_w \approx 7.0$ Papua New Guinea earthquake produced runup in excess of $12m$ and caused major loss of life. *Kawata et al.*, [1999]. The cause of the extreme runup has been attributed to a large ($4km^3$) slump along the continental margin of Papua New Guinea [*Synolakis* in review].

These two and another ten tsunamis in the past decade struck nearby coastlines, but had little impact farfield, leading us to reassess the paradigm for tsunami hazards in southern California. McCulloch (1985) had earlier described the local hazard as 'moderate' with the potential for $2-4m$ runup heights. Following the 1992 Cape Mendocino earthquake, McCarthy et al. (1993) reassessed the risk to southern California from locally generated tsunamis as moderate to high. As Synolakis et al. (1997a) noted, these investigations were obtained without hydrodynamic modeling, using only earthquake magnitude–to–tsunami height relationships developed for Japan, which may not be appropriate for other tectonic settings. The region offshore Southern California has numerous possible tsunamigenic hazards, including submarine faults and mass failures on unstable basin slopes [*McCulloch*, 1985; *Vedder et al.*, 1986; *McCulloch et al.*, 1989]. Computational tools now exist *Synolakis et al.*, [1997b] to allow quantitative modeling of the inundation potential from locally generated events. We present here results from modeling tsunamis that could be triggered from faulting and submarine mass movements within the Santa Barbara Channel.

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Regional Geologic Setting

Southern California lies astride a major transition between two tectonic provinces. The region to the south is dominated by northwest–trending, right–lateral strike-slip faults. The area to the north is characterized by west-trending mountain ranges–the Transverse Ranges–that have developed above west-trending reverse faults. Understanding of the thrust faults of the Transverse Ranges has increased dramatically over the past several decades, revealing the presence of several major reverse fault systems e.g. *Davis et al.*, [1989]; *Shaw and Suppe* [1994]; *Dolan et al.*, [1995].

The E–W Santa Barbara Channel forms the submerged western end of the Ventura basin *Vedder, et al.* [1969]. It is $\approx 130km$ long, extending from Point Conception in the west to the eastern end of Anacapa Island. The SB channel reaches a maximum depth of over $600m$ (fig. 1).

Several major active thrust fault systems, including the Channel Islands Thrust (CIT) of Shaw and Suppe (1994) lie offshore, beneath the Santa Barbara Channel. Potential coseismic deformation associated with this fault system represent a significant potential source for tsunami generation. Furthermore, the walls of the basin forming the channel are susceptible to submarine slope failures. At least two slope failures have been mapped in the central Santa Barbara Channel, one believed to have been seismically induced *Vedder et al.* [1986]; *McCulloch et al.* [1989]; *Edwards et al.*, [1993]. Recent studies reveal details of these two slope failures, additional failures along the northern wall of the channel, and several other possibly unstable regions *Greene and Maher,* [2000].

Historical Tsunamis and Earthquakes offshore Southern California

December 21, 1812 Santa Barbara. This one of the first reported large earthquakes in California appears to have generated a moderate-sized tsunami. The wave reportedly affected over $60km$ of the Santa Barbara coast *Toppozada et al.*, [1981]; *Lander et al.*, [1993]. This $M_w \approx 7.2$ earthquake caused extensive damage to the Spanish missions in the area. Historical sources report unusual ocean activity and high waves following the 12/21/1812 tremor *McCulloch* [1985]. Runup from this event is believed to have been as much as $4m$ at El Refugio, $40km$ west of Santa Barbara, and $\approx 2m$ in Santa Barbara and Ventura. Contemporary eyewitness accounts report that "the sea receded and rose like a high mountain", and "...it has been necessary for us to withdraw for now, more than half a league inland" *Toppozada et al.*, [1981]. Other accounts from survivors describe