Annual Report Summary, 2013

SOUTHERN CALIFORNIA EARTHQUAKE CENTER

Title of Project:
Earthquake Rupture and Tsunami Simulations:
Ventura-Pitas Point Fault System

Name of PI: Steven N. Ward
Institution: University of California, Santa Cruz

Abstract: In the past several years, geologists have presented new evidence that the Ventura and Pitas Point faults may 'link together' and rupture simultaneously in earthquakes far larger than had been previously believed. Because for much of their length, these faults lie under Santa Barbara Channel, a sizeable thrust event on this linked system could pose a serious and previously unrecognized hazard in the form of tsunami. In 2013 I have been modeling the tsunami and inundation extent of various faulting scenarios that developed by the Ventura Special Fault Study Group as well as my own rupture scenarios that arise from applications of 'ALLCAL–style' physics-based earthquake simulations.

An adjunct effort of this proposal in 2013 dealt with earthquake simulators. A major accomplishment up-stepped from the existing ALLCAL2 fault system to one that represents the newly released UCERF3 fault system as closely as possible. The UCERF3 fault system consists of down dip width, strike, dip, rake, geological slip rate and surface traces of 313 fault sections. Surface traces consist of two endpoints and perhaps several points in-between. As provided however, the UCERF3 fault system is not suitable for earthquake simulation. Fact is, no unique way exists to adapt the UCERF3 fault system for earthquake simulation. Certain assumptions have to be made. Accordingly, I call my product UCERF3-ES to differentiate the two sets (ES referring to Earthquake Simulator).

Technical Report: In following pages.

Exemplary Figure: Figure 2.

Publication:
(2013) "Ventura Tsunami" YouTube movie
http://www.youtube.com/watch?v=8KMjgWpdJzk

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Motivation

In the past several years, geologists have presented new evidence that the Ventura and Pitas Point faults may 'link together' and rupture simultaneously in earthquakes far larger than had been previously believed. Because for much of their length, these faults lie under Santa Barbara Channel, a sizeable thrust event on this linked system could pose a serious and previously unrecognized hazard in the form of tsunami.

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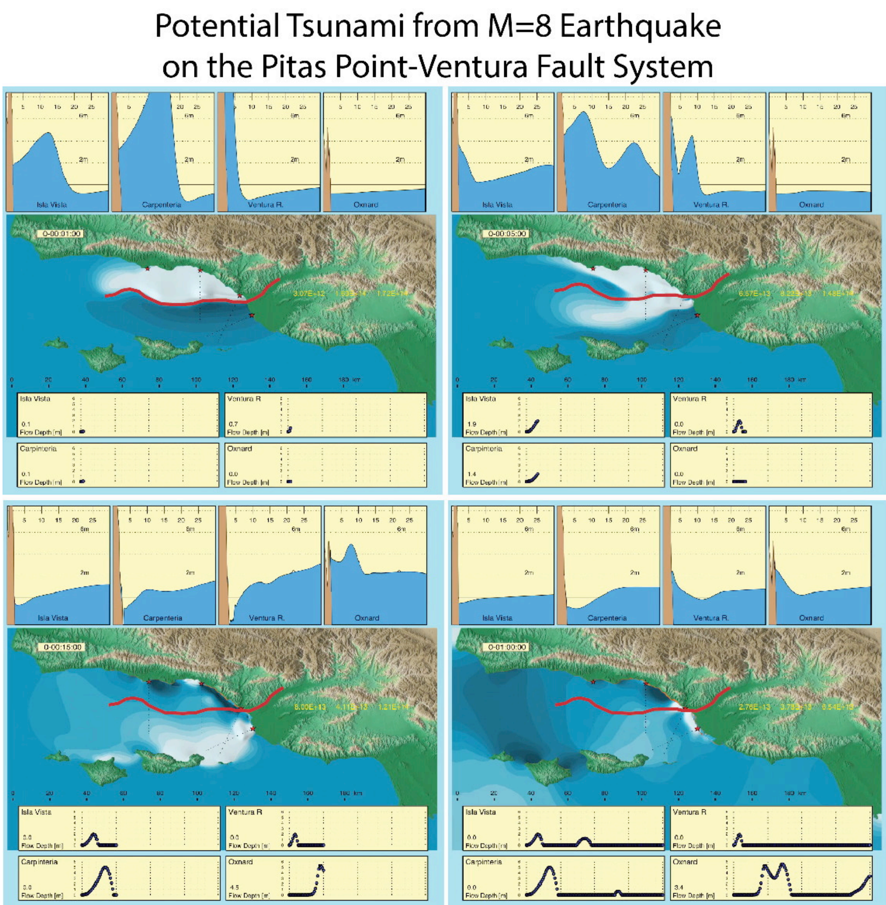

Figure 1. Tsunami simulation for an M=8 earthquake on the linked Ventura-Pitas Point fault system. The panels are at time 1, 5, 15 and 60 minutes. The fault strikes west out into the Santa Barbara Channel (red curve). Cross sections (above) and flow height histories (below) are shown for Isla Vista, Carpinteria, Ventura River and Oxnard. Find the movie link in the text box on Page 2.

New Sample Calculations.

Based on materials gathered at the SCEC/SFSG meeting in Ventura in August, 2013, I stitched together multi-element ALLCAL versions of Ventura, East Pitas Point and West Pitas point faults into a fairly continuous fabric stretching 102 km east to west. As advised by geologists, I placed pure thrust motion on the 40 degree dipping fault with variable slip ranging from 11 m in the east tapering to 4 m in the west. Magnitude of the sample earthquake was M_w=8. Details of fault geometry and slip distribution may be adjusted in the course, but the simulations here should be representative of the scale and type of tsunami effects expected from a linked Pitas Point-Ventura quake.

Figure 1 presents a map view of the Santa Barbara Channel. The Pitas Point-Ventura fault system (red line) runs straight west out from the coast on the north side of the Channel. Over a 60s rise time, the simulated quake pushes up a 100 km long ridge of water 10 meters high on the north, up-thrown side of the fault (Figure 1, upper left). On the southern, footwall side, the sea and seafloor drop by about 1 meter. Within four minutes, the water ridge collapses under its own weight and divides into two opposite traveling waves (Figure 1, upper right). By 15 minutes a 6 m wave has struck the coast between Oxnard and Carpinteria (Figure 1, lower left). Further west toward Santa Barbara, the wave drops to 2 meters height, more or less in proportion to the

Readers: To view the simulations of Figures 1, 2 and 3 drag & drop these links--
http://es.ucsc.edu/~ward/ventura-tsunami-map.mov
http://es.ucsc.edu/~ward/ventura-tsunami-map-c.mov
http://es.ucsc.edu/~ward/ventura-tsunami-pnw.mov
http://es.ucsc.edu/~ward/ALLCAL-Ventura.mov
http://es.ucsc.edu/~ward/Ventura-Tube.mov

assumed taper in fault slip. By 15 minutes, waves land on Channel Islands with strengths also decreasing westward in proportion fault slip. By 60 minutes, the wave has reached the beaches west of Los Angeles. Perhaps you might not have imagined, but a quake on the Ventura-Pitas point system produces a 2 m tsunami in the Venice Beach/LAX region. Two meters may not sound like much, but on a busy summer day with a beach full of visitors, it would be a mess. Reverberations in the Channel go on for some time. When the simulation cuts off at T=60 minutes, the coast near Oxnard is experiencing a third inundation episode (Figure 1, bottom

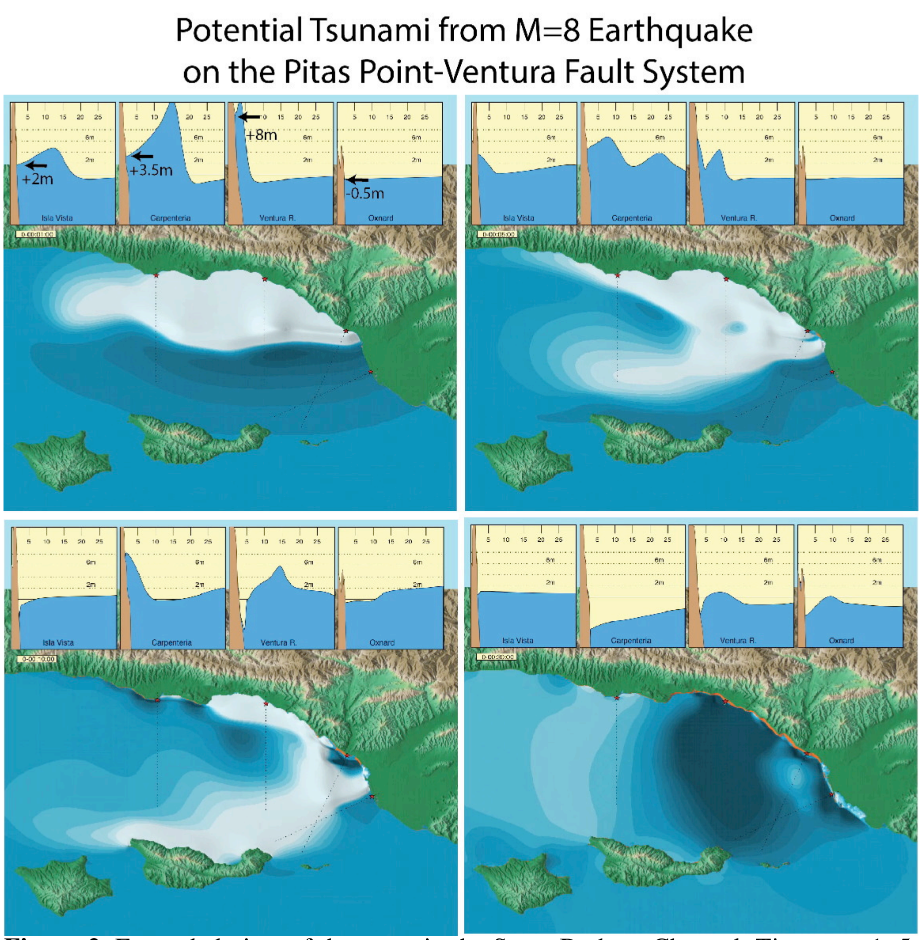

Figure 2. Expanded view of the wave in the Santa Barbara Channel. Times are 1, 5, 10, and 30 minutes. Arrows in the upper left panel show the co-seismic uplift values at the coast. Note several km of inundation in the Oxnard Plain, lower right. Find the movie link in the text box on Page 2.

right).

Close in to earthquakes, the extent of tsunami inundation depends both on wave height and any coseismic elevation change. When a coastal beach gets uplifted coseismically, so does the water. Uplift in itself causes no inundation, even if coastal water finds itself several meters above its former position. Especially telling in the Ventura-Pitas Point scenario where the fault approaches shore to the east. Near the mouth of the Ventura River, the coast uplifts by as much as 10 m, but the inundation is only about two meters (upper right, yellow box, bottom Figure 1). Simply, coseismically uplifted coasts are difficult to flood with tsunami. Oddly, the worst place to look for tsunami deposits might be close to the fault. On the down thrown side of the fault, the Oxnard plain faces more serious issues with inundation. Although the downthrown side sees bigger tsunami, paleodeposits there may be submerged or deeply buried.

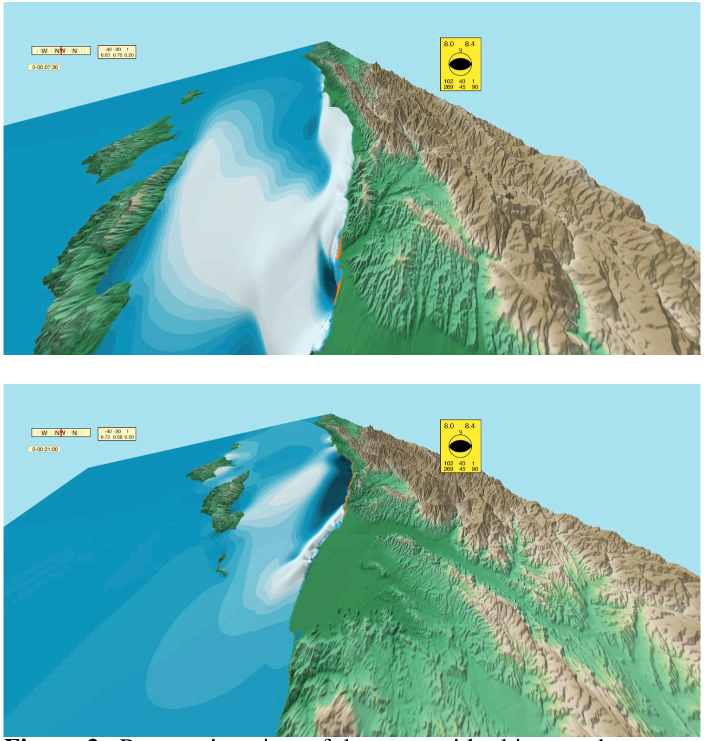

Figure 3. Perspective view of the tsunami looking northwest at t=7:30 and 21:00. Find the movie link in the text box on Page 2.

Figure 2 shows an expanded view of the wave in the Santa Barbara Channel. Times are 1, 5, 10, and 30 minutes. As I have said, for locations close to earthquakes, it can be complicated to separate variation in sea level due to wave action and variation in sea level due to elevation changes. These calculations however, contain both types of information and they should be helpful in interpreting what may, or may not, occur at a given site. Arrows in the upper left panel of Figure 2 show the coseismic uplift values at the coast. Coastal water

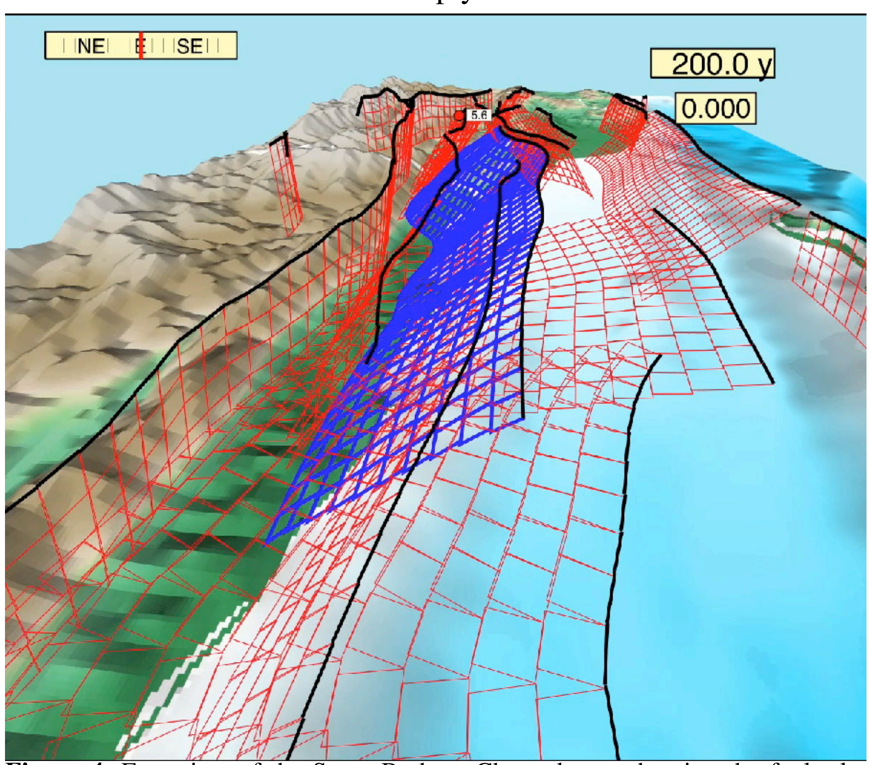

Figure 4. East view of the Santa Barbara Channel area showing the fault elements of the ALLCAL earthquake simulator. The blue highlighted squares are the new addition -- the linked Ventura Pitas Point fault. Find the movie link in the text box on Page 2.

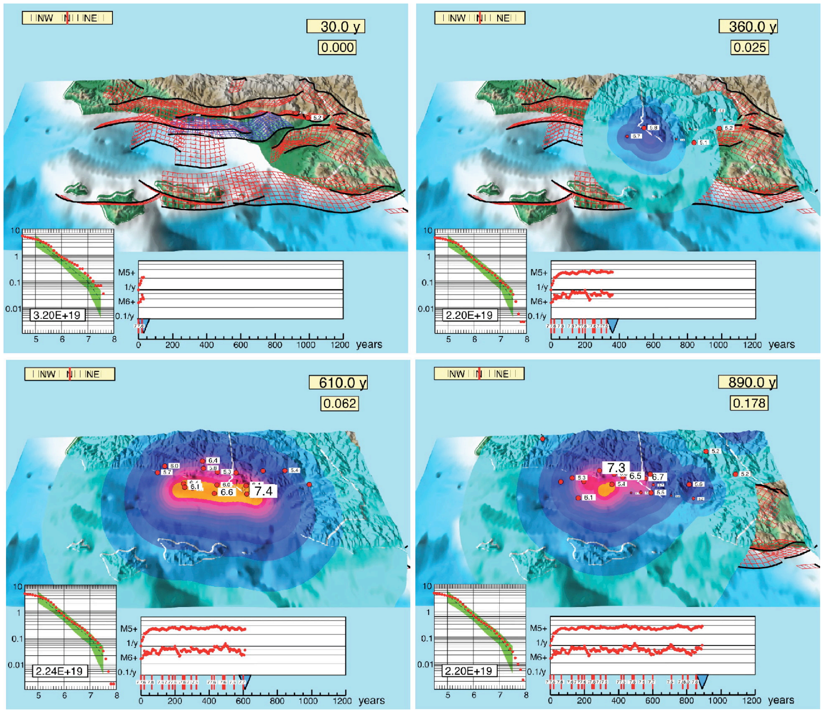

Figure 5. Frames from a 1000 year run on ALLCAL on the Santa Barbara Channel Faults. Find the movie link in the text box on Page 2.

uplifts the same amount as adjacent coasts, so any inundation must come from off shore water at higher elevation still. Carpentaria slough uplifted 3.5 m coseismically, but still experienced tsunami of 6.5 m from bigger uplifts offshore. This looks like a good place for tsunami prospecting. Figure 3 shows a perspective view of the wave looking northwest at peak inundation. Fly-by and perspective views like this helps many people visualize aspects of the process that a sample map view can not.

The SCEC CFM developers have recently posted (November 11, 2013) new models for the Ventura/Pitas Point faults. The east view in Figure 4 illustrates the complexity of the region with many crosscutting faults. Overlapping and crosscutting faults can be a problem for earthquake simulators. The rectangles are (2 x 2 km) fault elements employed in ALLCAL. The blue rectangles represent the new curved Ventura/Pitas Point fault.

Figure 5 shows frames from a 1000 year run of ALLCAL with the new faults. The run seems fairly stable in spite of the crosscutting faults. The largest quake on the Ventura/Pitas Point in 1000 years however, was only M7.4. If the goal is the produce the occasional M8 quakes, like the scenario in Figure 1, fault strength will have to be increased considerably in subsequent runs. Recurrence of such events would be probably far less than one per 1000 years.

UCERF3 Fault System Adapted to ALLCAL: UCERF3-ES

An adjunct effort of this proposal in 2013 dealt with earthquake simulator improvement. A major up step was taken from the existing ALLCAL2 fault system to one that represents the newly released UCERF3 fault system as closely as possible. The eventual objective is to compare earthquake simulator output with UCERF3 forecasts.

The UCERF3 fault system consists of down dip width, strike, dip, rake, geological slip rate and surface traces of 313 fault sections. Surface traces consist of two endpoints and perhaps several points in-between. As provided however, the UCERF3 fault system is not suitable for earthquake simulation. Fact is, no unique way exists to adapt the UCERF3 fault system for earthquake simulation. Certain assumptions have to be made. Accordingly, I call my product UCERF3-ES to differentiate the two sets (ES referring to Earthquake Simulator).

UCERF3 fault set has >16,000 km total along strike length. The current version of UCERF3-ES employs a 3 km length spacing producing 5286 elements along strike. The current UCERF3-ES includes 25,586 elements. The previous ALLCAL2 model had ~15,000 elements, so UCERF3-ES is a definite expansion in scope.

There are several steps needed to take UCERF3 to UCERF3-ES:

IIa. Fault Continuity
IIb. Fault Trace Smoothing
IIc. Fault Trace Sampling – Along Strike Element Length
IId. Fault Width Sampling – Down Dip Element Width
IIe. Down Dip Element Positions - Mean Strike Scaling.
IIf. Slip Rate Smoothing

These steps are discussed in my 2014 SCEC proposal "An Earthquake Simulator for UCERF3", so I will not re-hash them here.

UCERF3-ES Preliminary Results

The ALLCAL simulator generates dynamic ruptures from magnitude 8+ down to about magnitude 3, so a 400 year run on UCERF-ES produces ~10,000 events. Please view a movie of this at: http://es.ucsc.edu/~ward/ucerf3-es-400y.mov . Every one of the thousands of flashes in this movie is a genuine, expanding 3-D dynamic rupture. Another movie "flies over" 1000 years of California quakes: http://es.ucsc.edu/~ward/ucerf3-es-map-flyover.mov . The latter movie highlights the complexity of the fault system as well as improvements in graphic style (Figure 6).

I put a lot of stock in visual presentations of science. Lately, I have been publishing four minute YouTube movies of various simulations (http://www.youtube.com/user/ingomar200). Construction of these movies aligns perfectly with SCEC's mission to broaden the scope of Education and Outreach. Earthquake simulation sequences of this type make perfect material for video lectures. I believe that eyes catch these movies from many who might not otherwise think much about earthquakes or science in general.

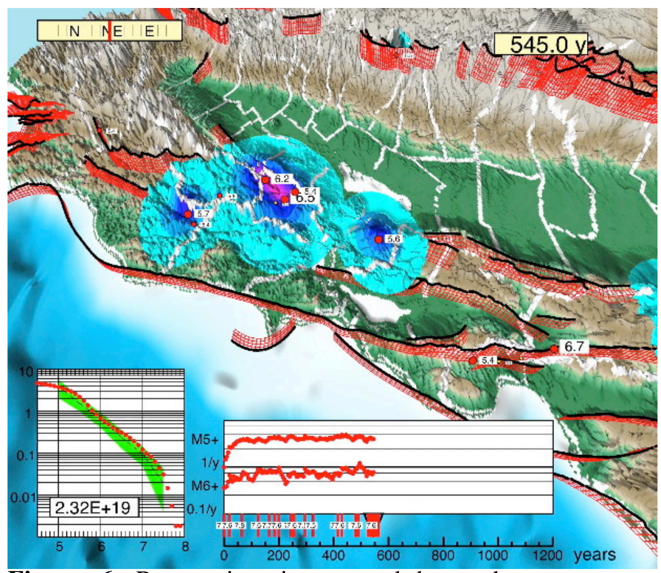

Figure 6. Perspective view toward the northeast over central and northern California that catches several moderate simulated quakes on inland faults. This frame is from the "flyover" movie link listed in the text.

Publications: (2013) "Ventura Tsunami" YouTube movie
http://www.youtube.com/watch?v=8KMjgWpdJzk