CAL POLY

CIVIL & ENVIRONMENTAL ENGINEERING
CAL POLY - SAN LUIS OBISPO, CA

TSUNAMIGENIC PROBABILISTIC FAULT DISPLACEMENT HAZARD ANALYSIS FOR SUBDUCTION ZONES

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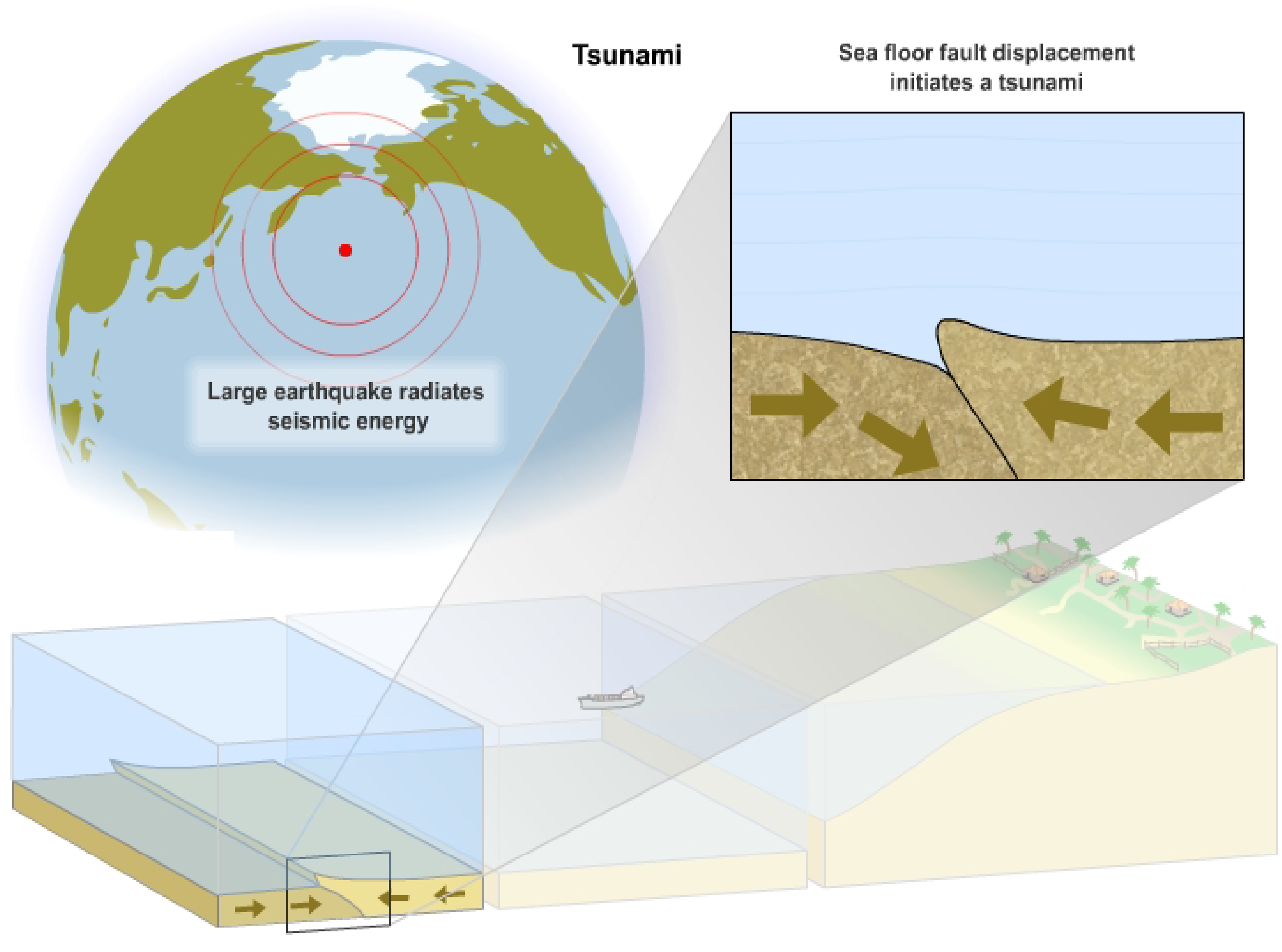

Tsunami
Sea floor fault displacement
initiates a tsunami
Large earthquake radiates
seismic energy

Research Objectives:

Develop a probabilistically methodology for tsunamigenic fault displacment hazard analysis to allow for performance-based tsunami engineering.

Workshop Talking Points:

- probabilistic methodology
- quantity and quality of data for statistical analysis of phenomena
- models and methods used to "fit" the data for predictive purposes
- observed or prescribed probability distributions (limits, trucation, etc)
- working definition of fault rupture/ground displacement

PSHA – Probabilistic Seismic Hazard Analysis (after Cornel, 1968 & 1971)

$$\nu(a) = N_{M\,\min} \int_M \int_R P\left(A > a \middle| m, r\right) \cdot f_M\left(m\right) \cdot f_R\left(r\right) \cdot dm \cdot dr$$

Annual rate of exceedence of ground shaking

Annual number of EQ's greater than Mmin

Conditional probability density function for ground shaking

Probability density function for magnitude

Probability density function for distance

PFDHA – Probabilistic Fault Displacement Hazard Analysis (after Youngs et al., 2003)

$$\nu(d) = N_{M\,\min} \int_{M} P\left(D > d \middle| m\right) \cdot f_M\left(m\right) \cdot dm$$

<u>Annual rate of exceedence of surface displacement</u>

<u>Annual number of EQ’s greater than Mmin</u>

<u>Conditional probability density function for surface displacement</u>

<u>Probability density function for magnitude</u>

Magnitude Recurrence

$$\nu(d) = N_{M\,\min} \int_M P\left(D > d \middle| m\right) \cdot f_M(m) \cdot dm$$

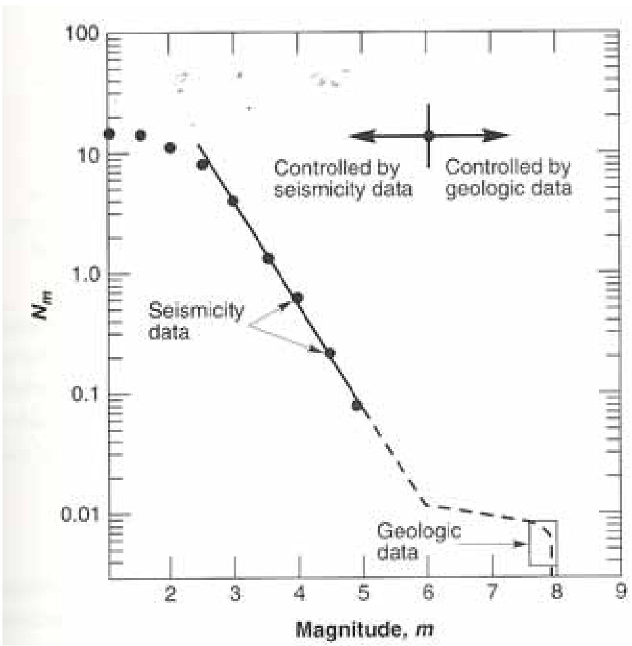


Figure 4.12 Inconsistency of mean annual rate of exceedance as determined from seismicity data and geologic data. (After Youngs and Coppersmith, 1985.)

Characteristic Model
(Youngs & Coppersmith, 1985)

$$f(m) = \begin{cases} \dfrac{1}{1+c_2} \cdot \dfrac{\beta \cdot \exp\left(-\beta(\overline{M}_{char} - M_{\min} - 1.25)\right)}{1-\exp\left(-\beta(\overline{M}_{char} - M_{\min} - 0.25)\right)} & \text{for} \quad \overline{M}_{char} - 0.25 < M < \overline{M}_{char} + 0.25 \\[2ex] \dfrac{1}{1+c_2} \cdot \dfrac{\beta \cdot \exp\left(-\beta(M - M_{\min})\right)}{1-\exp\left(-\beta(\overline{M}_{char} - M_{\min} - 0.25)\right)} & \text{for} \quad M_{\min} \le M \le \overline{M}_{char} - 0.25 \end{cases}$$

Conditional probability density function for surface displacement

$$\nu(d) = N_{M\,\min} \int_M P(D > d|m) \cdot f_M(m) \cdot dm$$

$$P(D > d|m) = P(SR|m) \cdot P(D > d|m, SR)$$

Conditional probability distribution of surface rupture given the occurrence of an earthquake

Conditional probability distribution for a specific level of displacement given the occurrence of surface rupture

Conditional probability distribution of surface rupture given the occurrence an earthquake $P(SR|m)$

Empirical Cumulative Probability Distribution of SR (Wells and Coppersmith, 1993)

distribution form

$$P(SR|m) = \frac{e^{f(x)}}{1+e^{f(x)}}$$

$$f(x) = a + b \cdot M$$

type of regression

-least squares

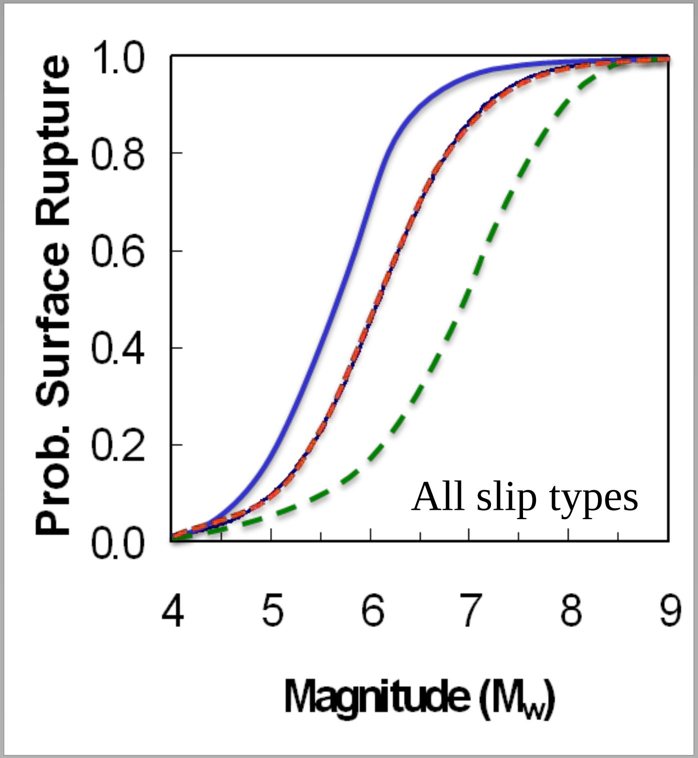
-orthogonal

-Bayesian

SS-shallow shearing

N-deep tensional

R-deep compressional



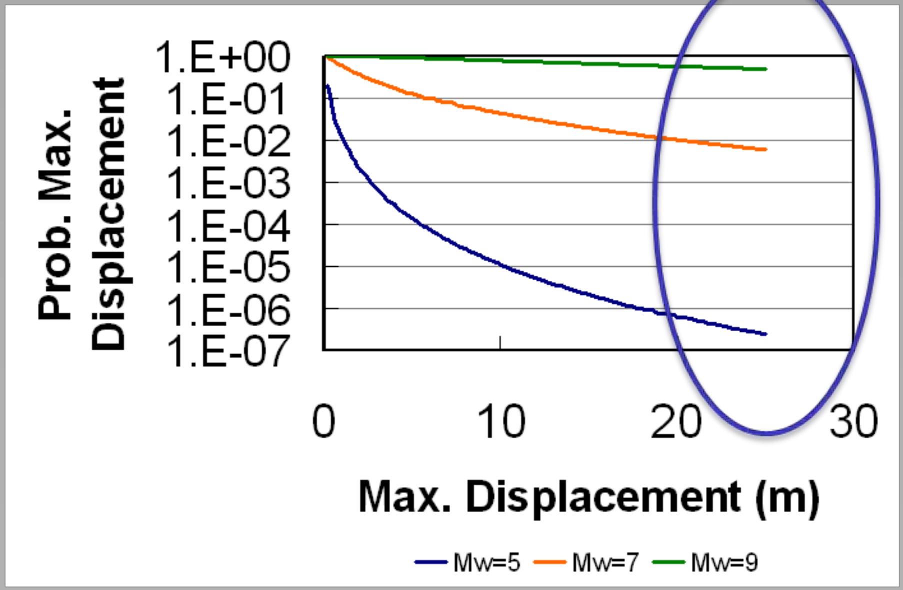
Conditional probability distribution for a specific level of displacement given the occurrence of an earthquake with surface rupture $P(D > d|m, SR)$

$\log(D) = a + b \cdot M$ regression on log(D)

$$P(D > d|m, SR) = 1 - \Phi\left(\frac{\log(d) - \mu}{\sigma}\right)$$

Cumulative Lognormal Distribution

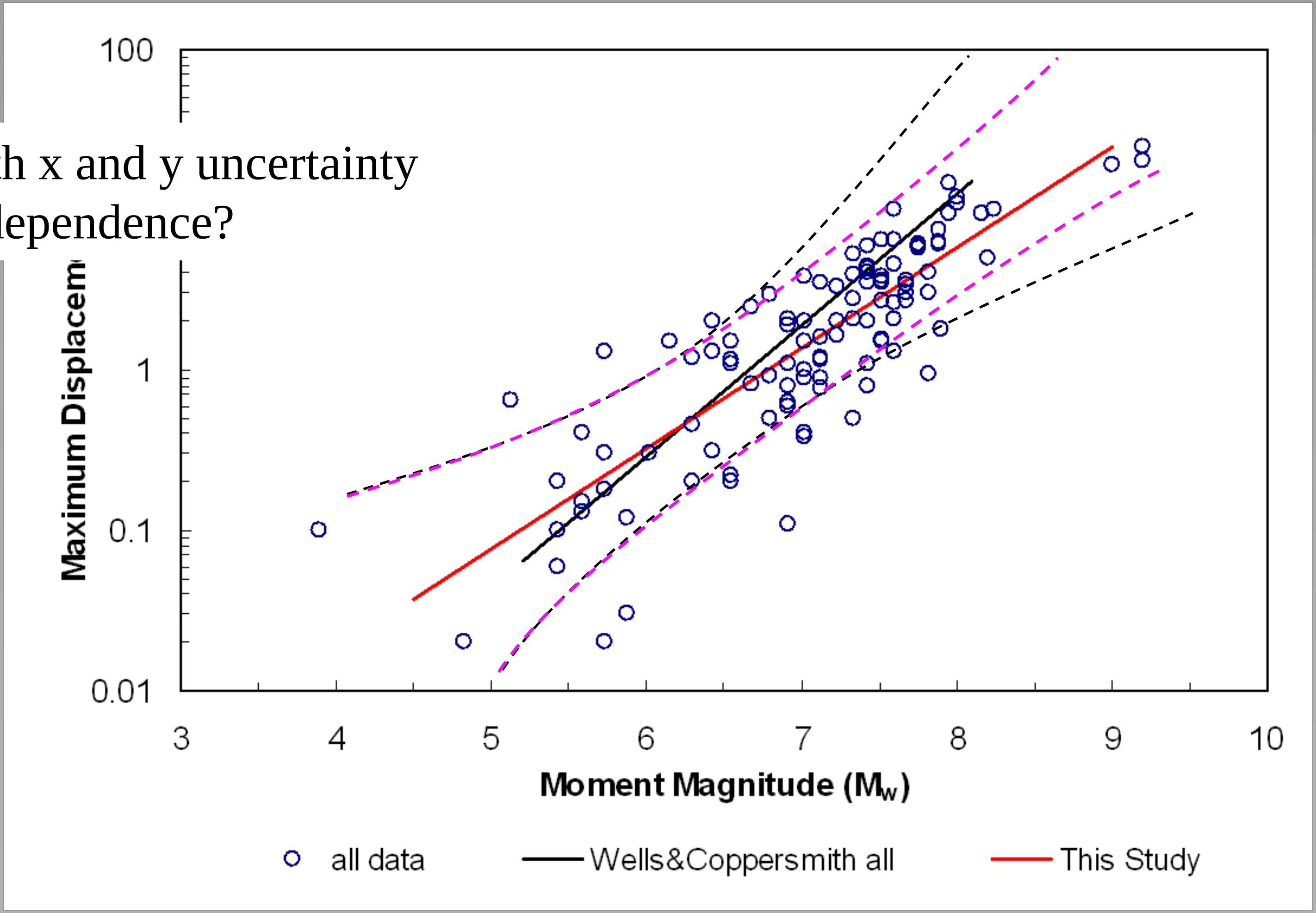
truncated lognormal?
gamma distribution?



Regression extended to Subduction Zone Magnitudes

	a	*b*	**standard deviation**
This Study	-4.27	0.63	0.50
Wells and Coppersmith	-5.46	0.82	0.42

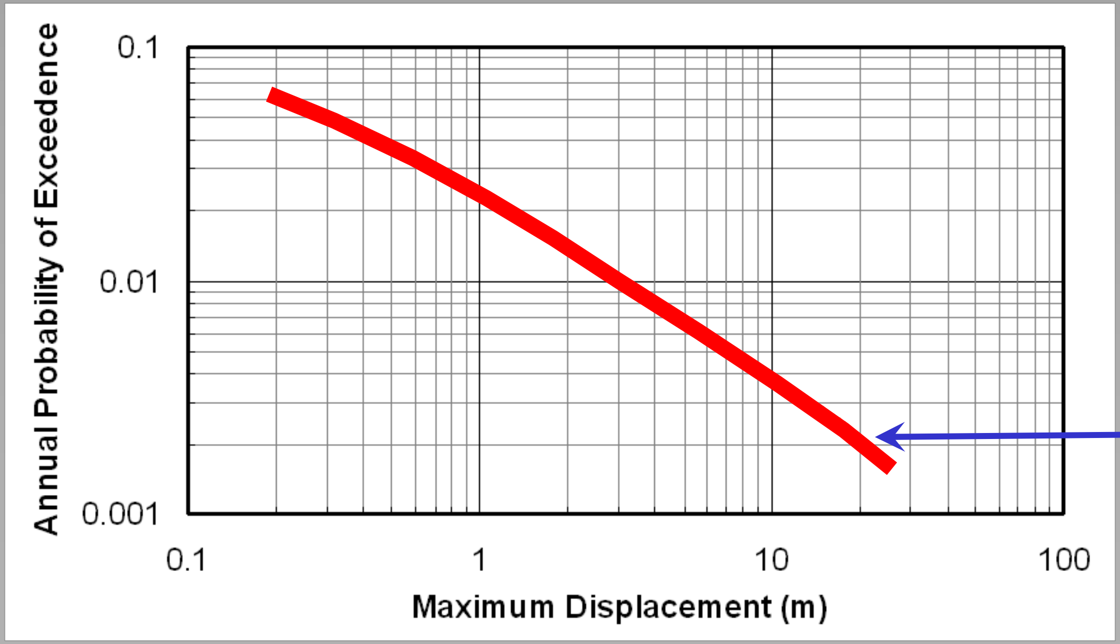
-variance with x and y uncertainty
-magnitude dependence?



Cascadia Example

Source Parameters:

- fault rupture area of roughly 1000 km by 50 km
- shear modulus of $3.5(10)^{11}$ dynes/cm^2
- minimum and maximum magnitude of 5.0 and 9.0
- b-value of 0.8
- slip rate of 33 mm/yr (average between the N and S sections, Miller et al., 2001)



~20 m displ. circa 1700
(Satake et al. 2003)

10% in 50yr
(~475 yr)

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Thank you