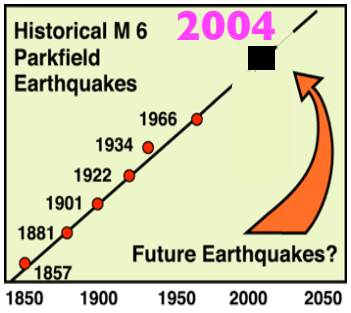
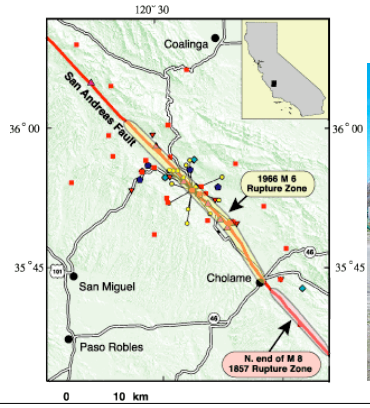
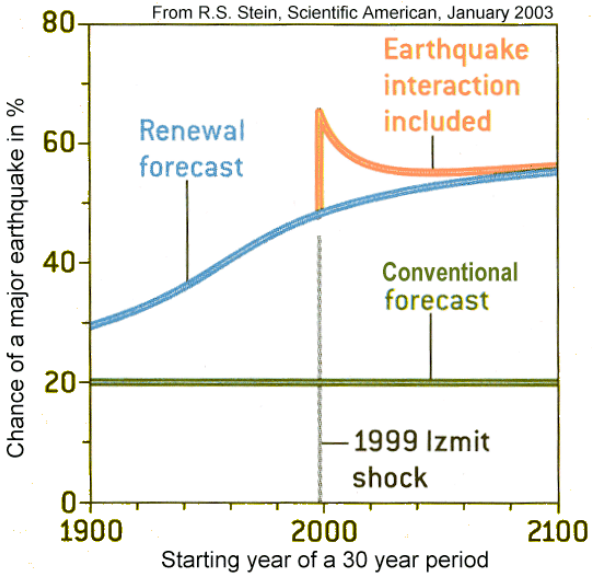
Forecasting **when** a large earthquake is likely to happen

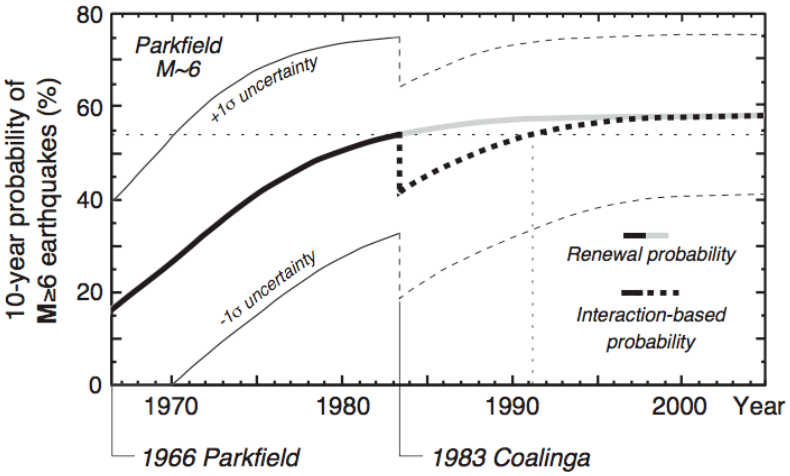
- earthquakes do not happen at regular time intervals
- even at Parkfield CA, famous for "regular" earthquakes, the time spacing is not actually regular





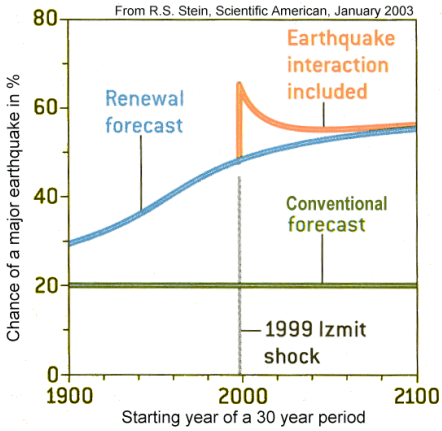
Three types of forecasts





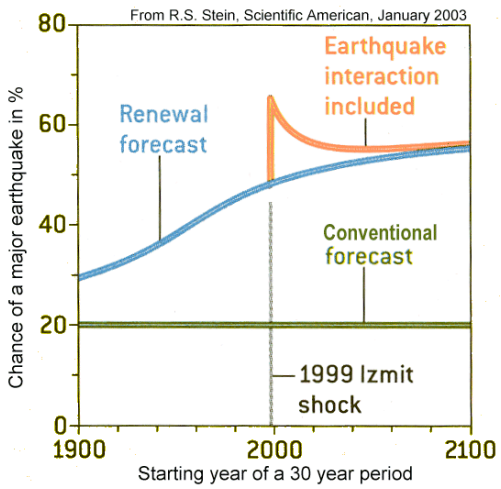
Conventional forecast

Probability remains constant. We assume this when we don't know standard deviation of the return period, or if the standard deviation is big (i.e. the earthquakes occur at seemingly random time intervals).



Renewal forecast (blue line):
If stress increases gradually, then the chance of a damaging shock grows as time passes. Requires:

- mean recurrence time
- **standard deviation**
- **time since the last earthquake**

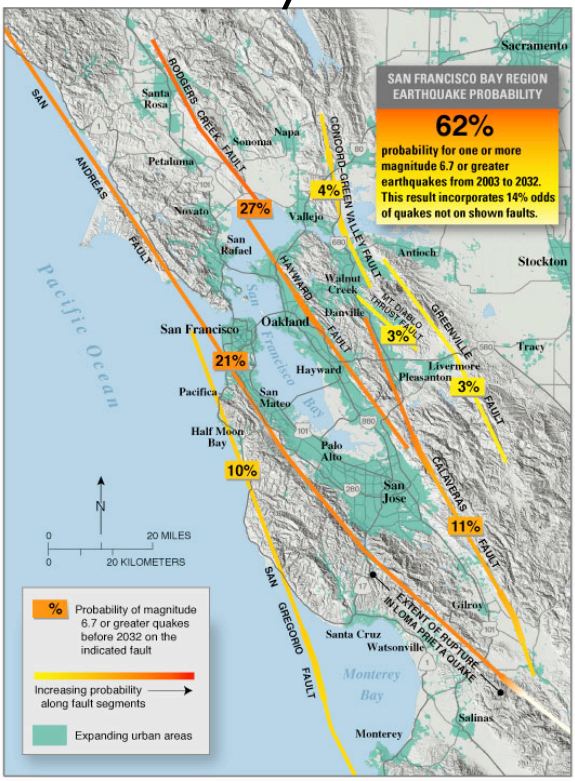


Renewal forecast with earthquake interaction (red line):
Effects of Coulomb stress changes caused by nearby earthquakes may cause probabilities of another shock to rise *or fall* temporarily.

Renewal Forecast in the SF Bay Area

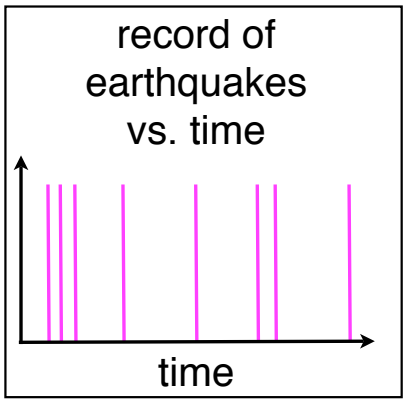
Probability of a **M 6.7 or larger** earthquake in the San Francisco Bay Area **between 2003 and 2032**

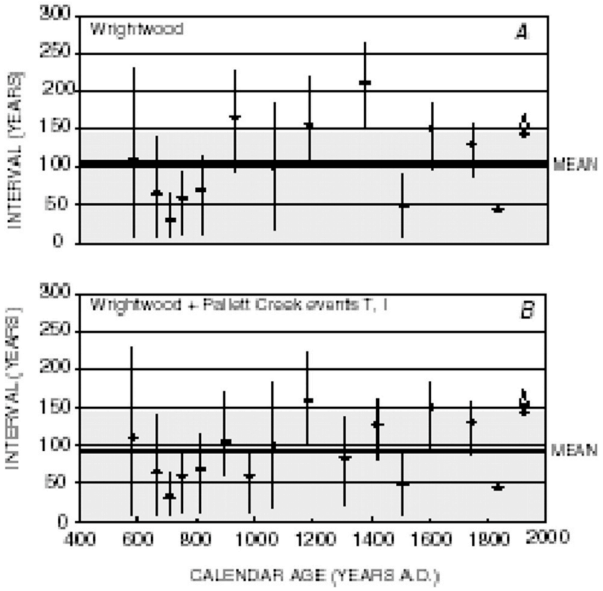
Probability of a large quake in a region includes probabilities on *all of the local faults*



http://pubs.usgs.gov/fs/2003/fs039-03/

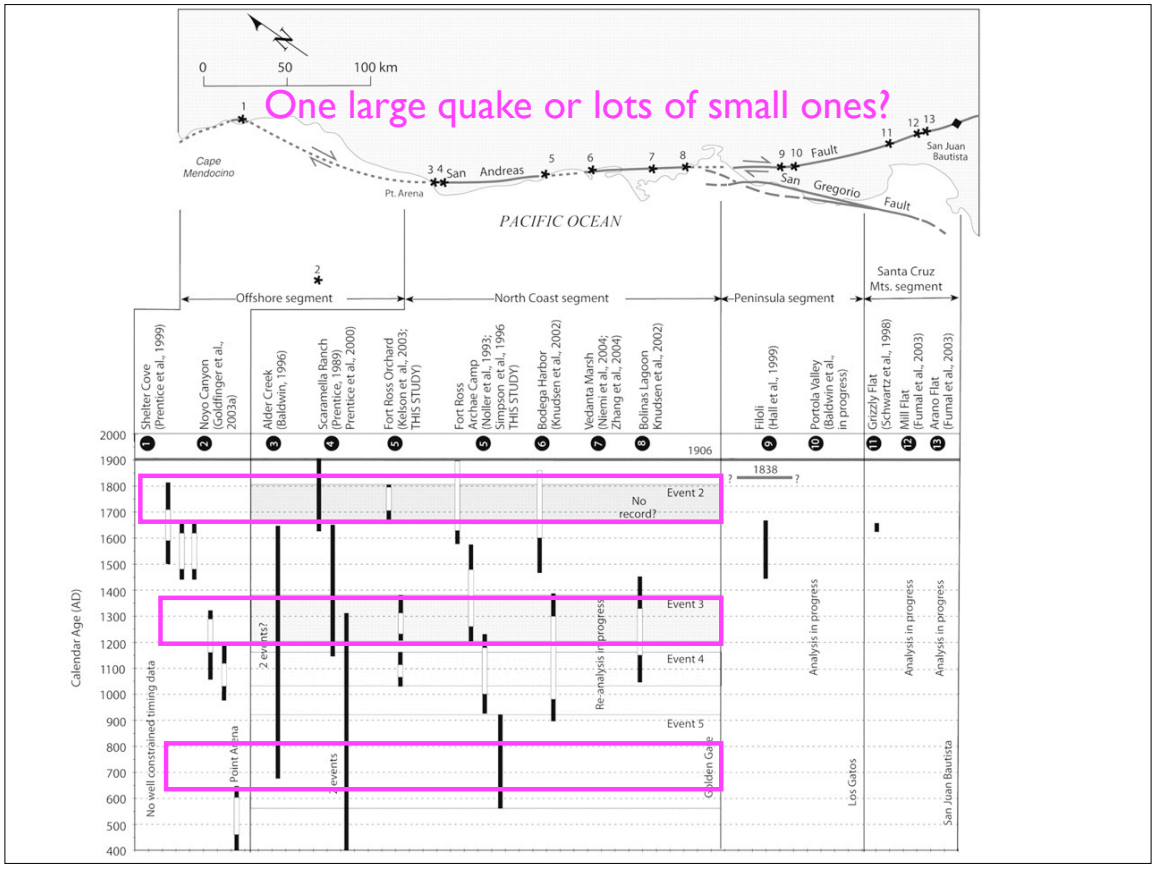
Renewal forecast



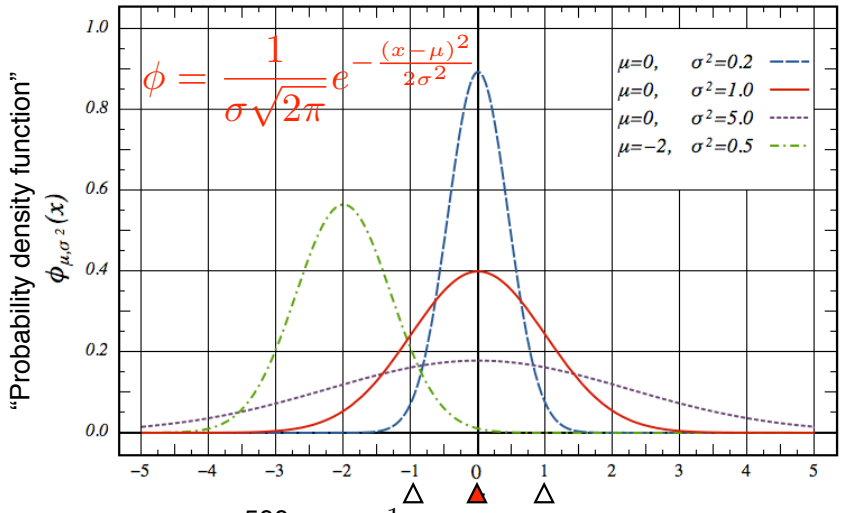


For each fault, requires

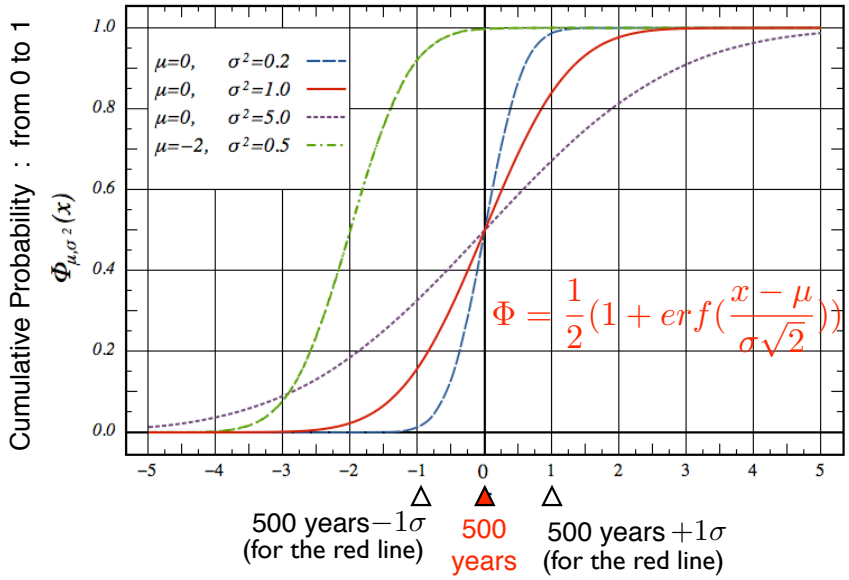
- mean recurrence time
- **standard deviation**
- **time since the last earthquake**

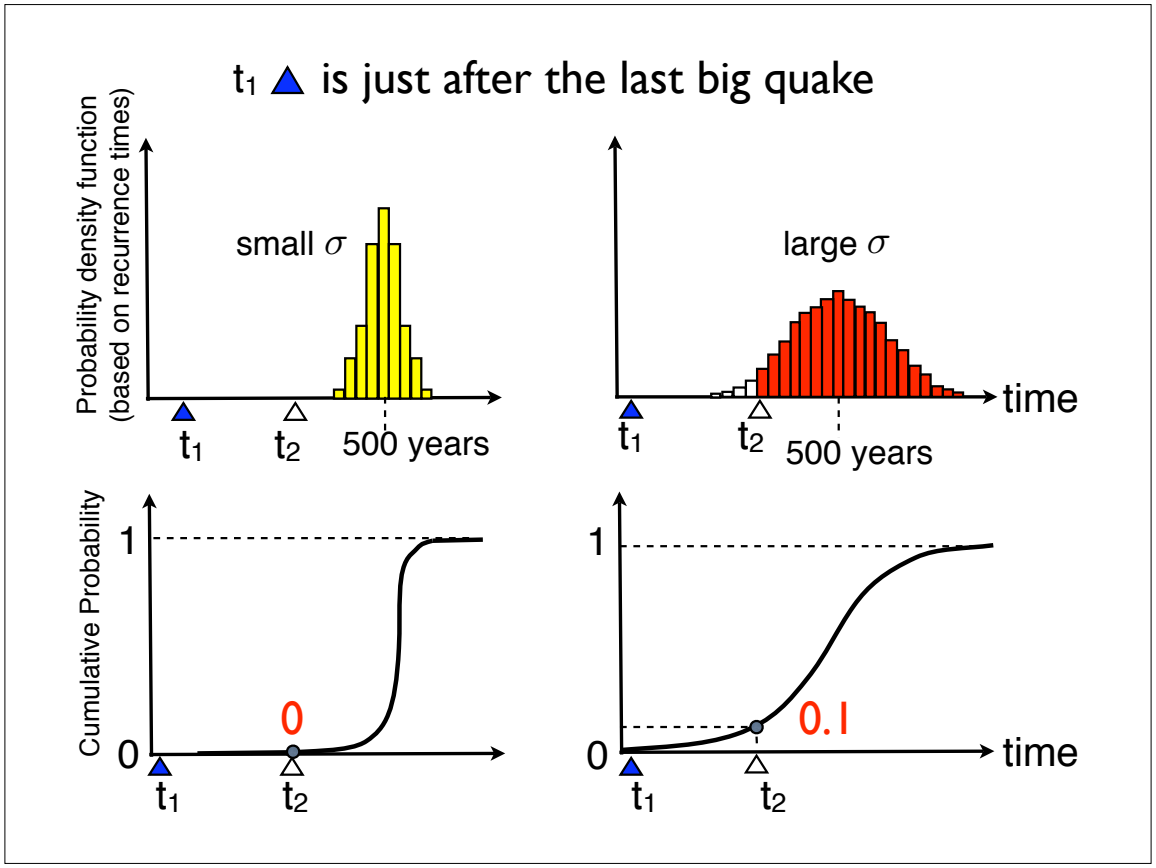


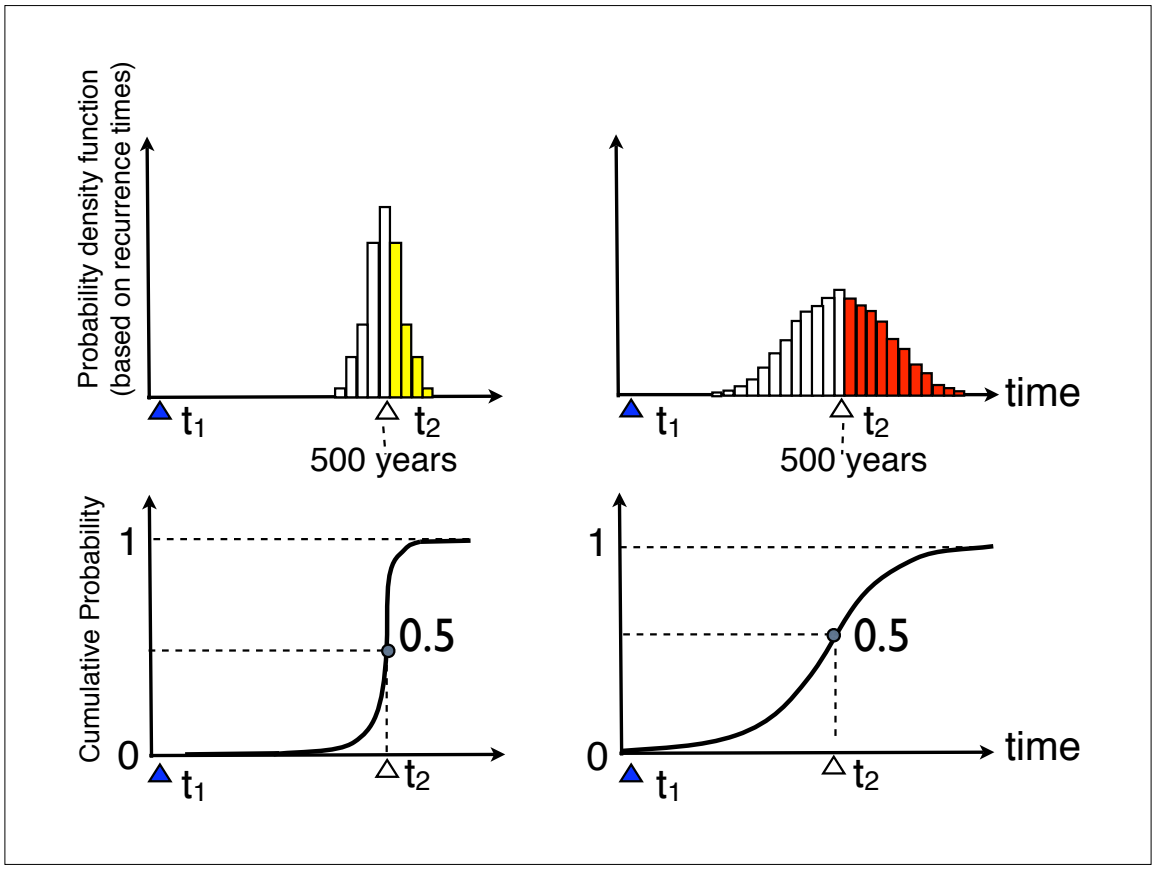
Assume the recurrence times fit a Gaussian (normal) distribution



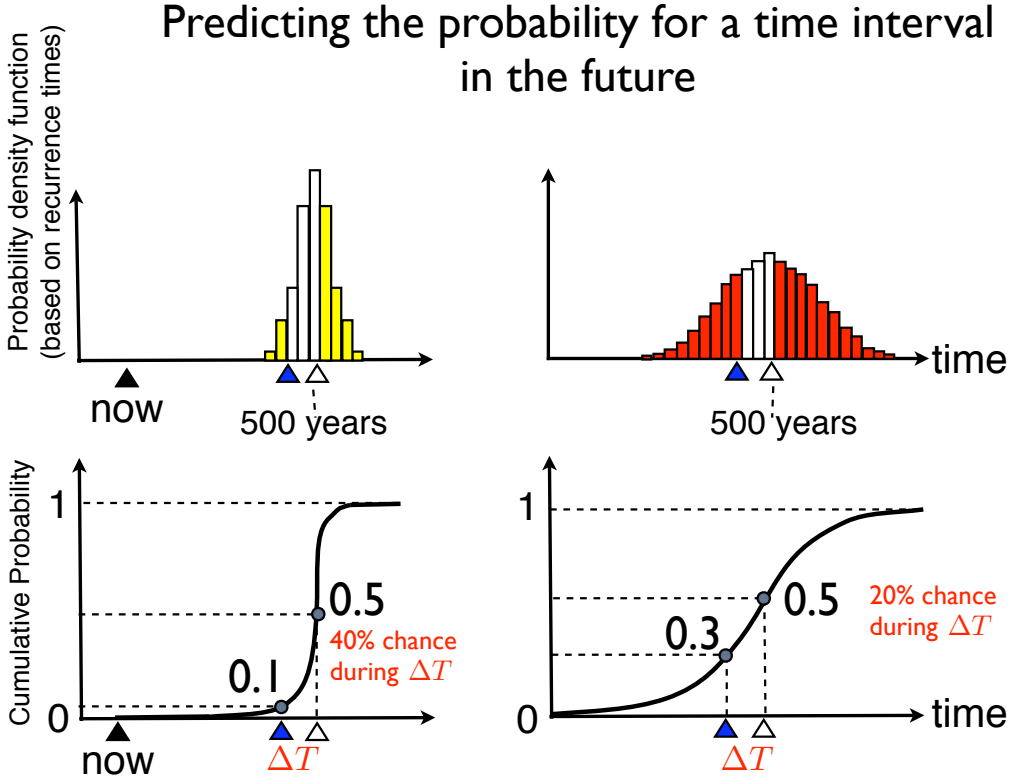
Integrate the Gaussian to get the probability of an earthquake over a time interval



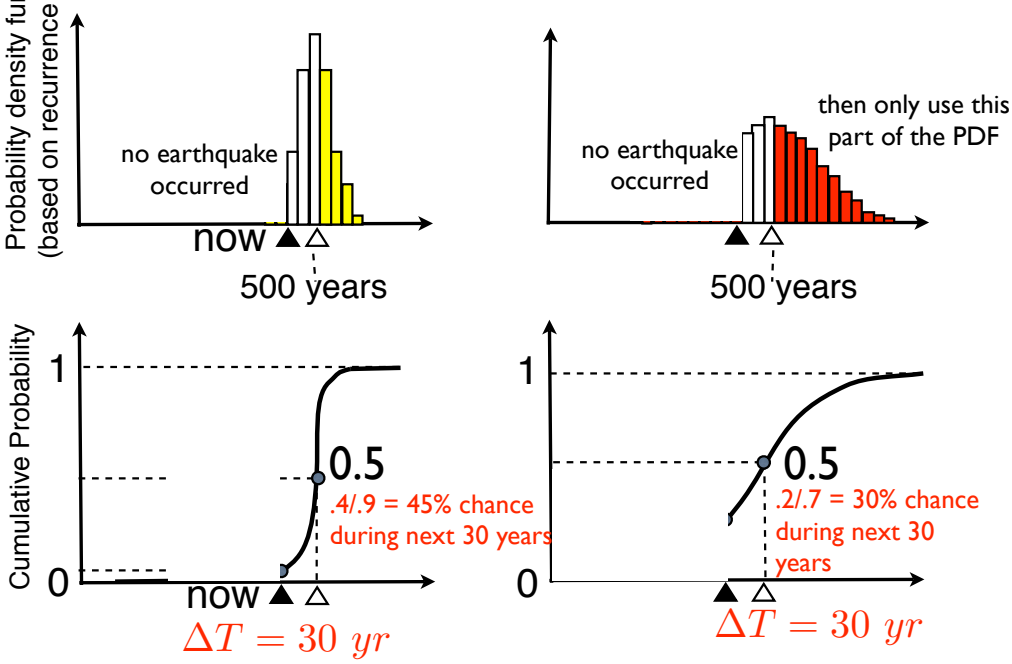

t1 ▲ is just after the last big quake
Probability density function
(based on recurrence times)
small σ
large σ
time
t1
t2
500 years
Cumulative Probability
1
0
0
0.1
time


Probability density function
(based on recurrence times)
time
t1
t2
500 years
Cumulative Probability
1
0
0.5
time

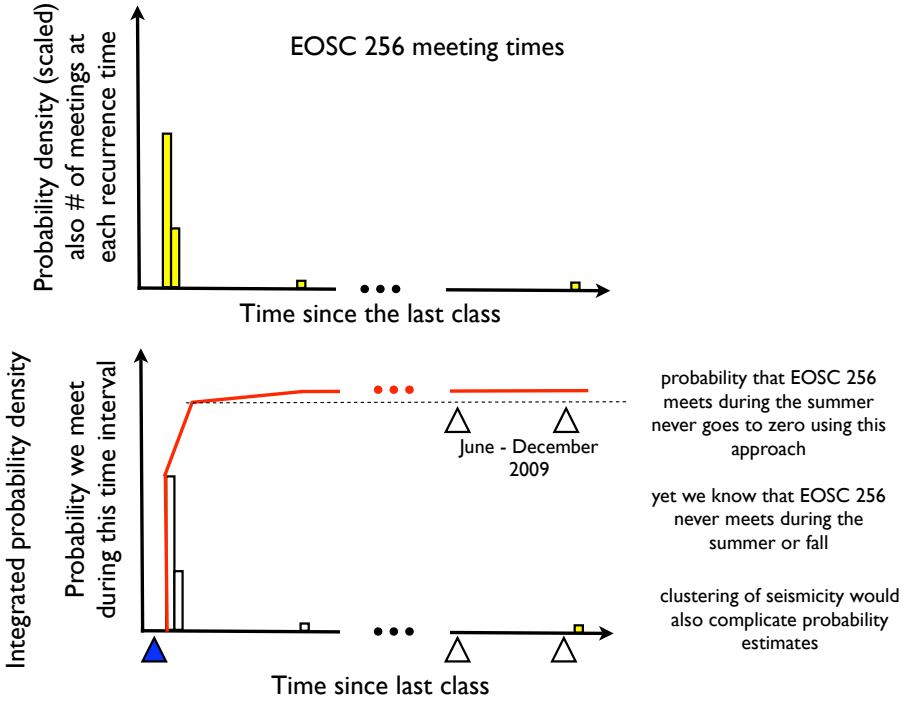
Predicting the probability for a time interval in the future



If we know the quake has not happened yet... and we are at time "▲"



Earthquake clustering: non-Gaussian (or lognormal) distribution



Cascadia Subduction Zone Fault

drowned ancient stumps from tress killed by sudden subsidence in a Cascadia earthquake

M9 (Sumatra-like) earthquakes every (300 to 1300!) years

wood fragments sandwiched between sand layers where land surface dropped suddenly and killed a mature forest

plus catastrophic undersea debris flows (turbidites), and other geological evidence

Uncertainties in mean and standard deviation of the return period: Different studies suggest different return periods for interplate earthquakes at the Cascadia Subduction Zone as discussed earlier. The two widely referred to estimates are 590 ± 105 [14] and 520 ± 330 years [15]. The former is used for lower bound, the latter for upper bound estimates.

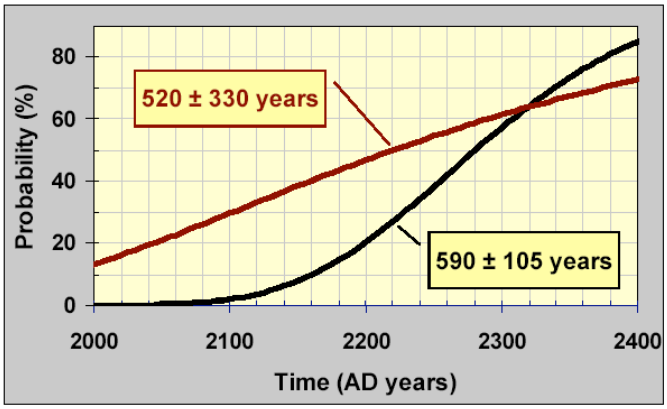


Figure 6. The effect of return periods on the probability estimations

14. Adams J, Weichert D. "Near-term probability of the future Cascadia megaquake." Proceedings of the Workshop on Paleoseismology, United States Geological Survey Open-File Report 94-568, 1994.
15. Atwater BF, Hemphill-Haley E. "Recurrence intervals for great earthquakes of the past 3500 years at the northeastern Willapa Bay, Washington." United States Geological Survey Professional Paper 1576, 1997.

Onur and Seeman, 2004

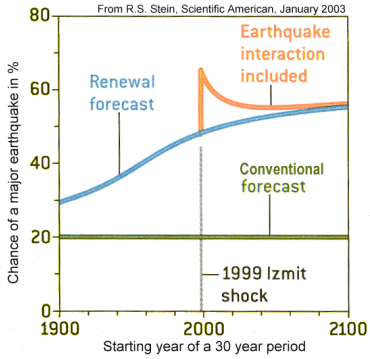


Table 4. Probabilities of a Cascadia megathrust earthquake within the next 10, 50, and 100 years

Cascadia megathrust earthquake occurrence probability (%) within the next:								
10 years			50 years			100 years		
Lower	Best	Upper	Lower	Best	Upper	Lower	Best	Upper
0.034	7.5	15	0.31	11	22	2.3	17	31

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PROBABILITIES OF SIGNIFICANT EARTHQUAKE SHAKING IN COMMUNITIES ACROSS BRITISH COLUMBIA: IMPLICATIONS FOR EMERGENCY MANAGEMENT

Tuna ONUR, and Mark R. SEEMANN

Earthquake forecasting summary

We can usually forecast where damaging earthquakes will be (seismic gaps on known faults) but we are still often surprised (e.g., blind faults, intraplate faults)

We can usually forecast their effects (e.g., strength and duration of shaking, tsunami genesis)

We cannot predict the timing of earthquakes very well (though *probabilities* over long time periods can sometimes be estimated)