Characterizing Megathrust Recurrence Probabilities in the Pacific Northwest

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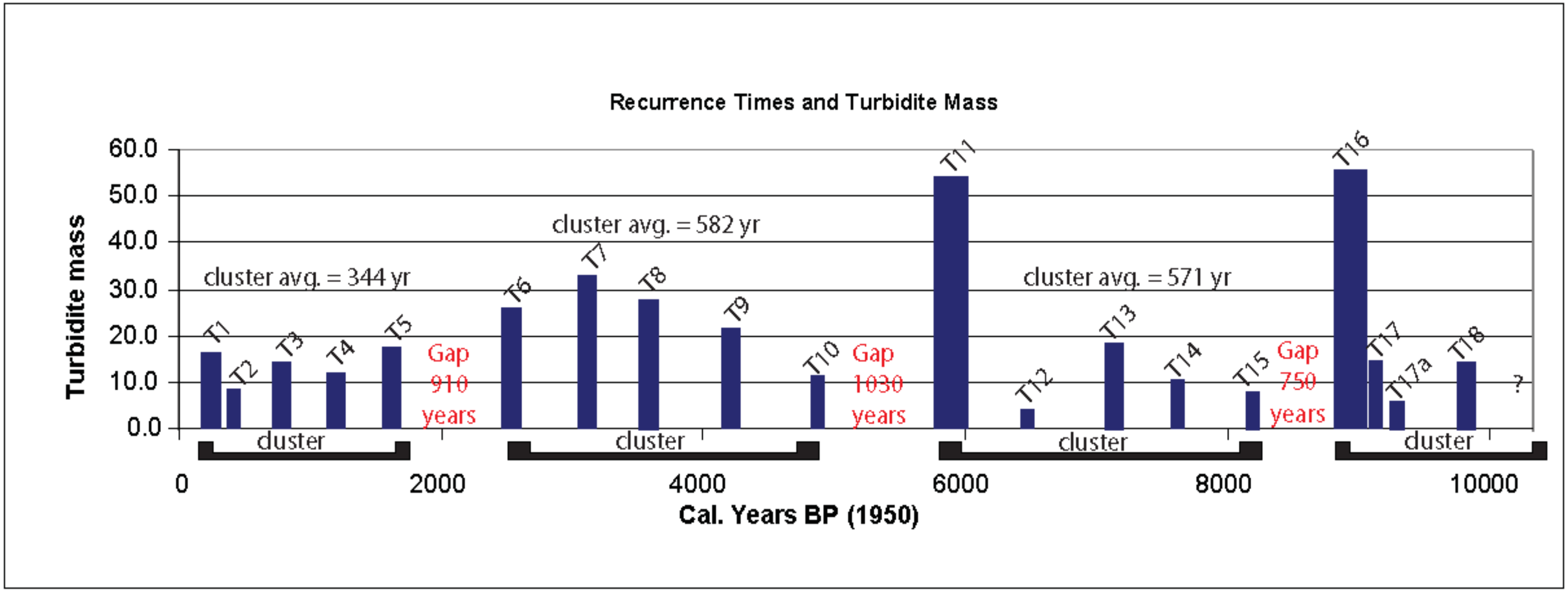
Basic Data

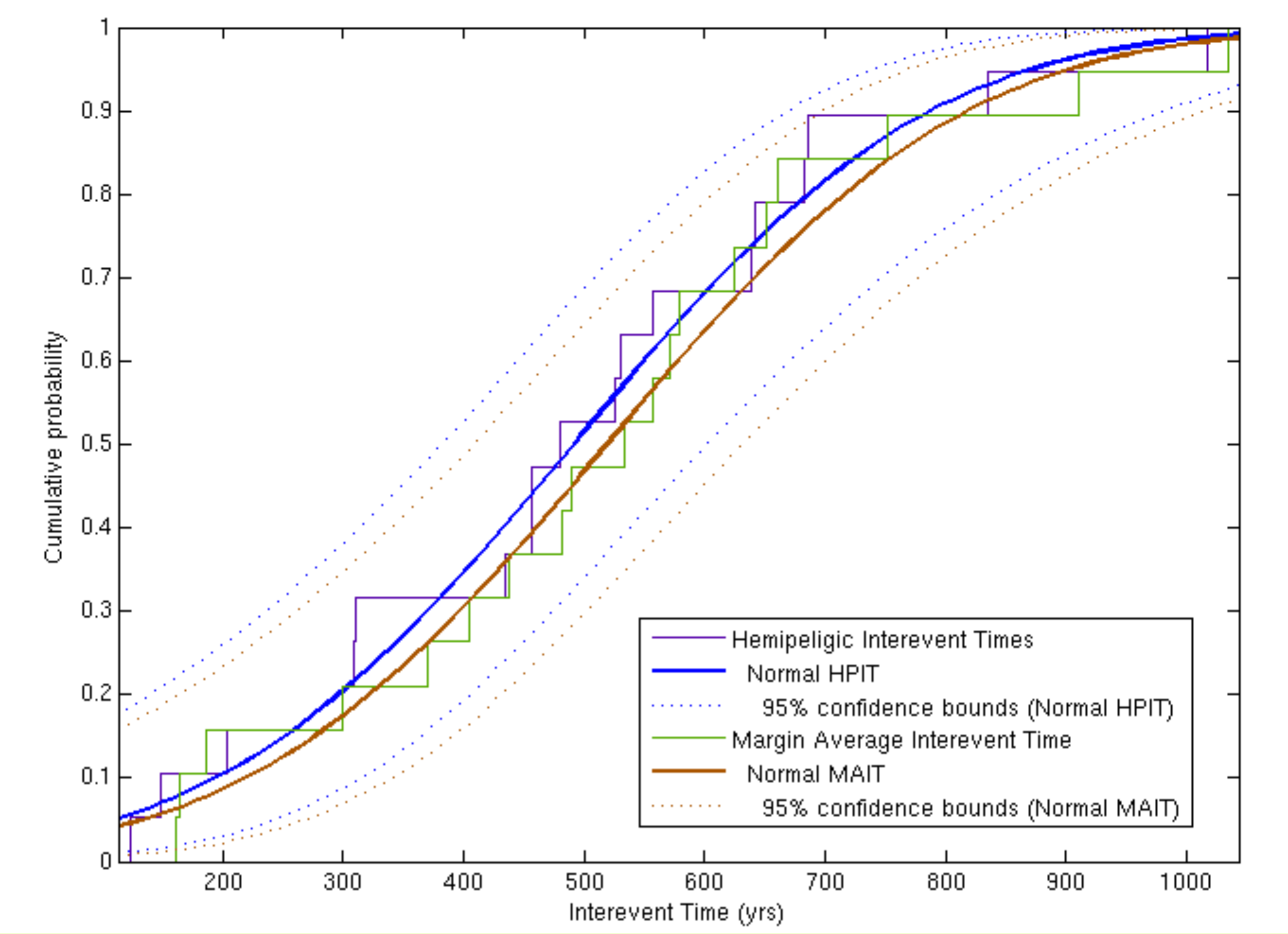


- (Nominal pattern from Goldfinger, and resampled catalogs generated by Kulkarni and others)

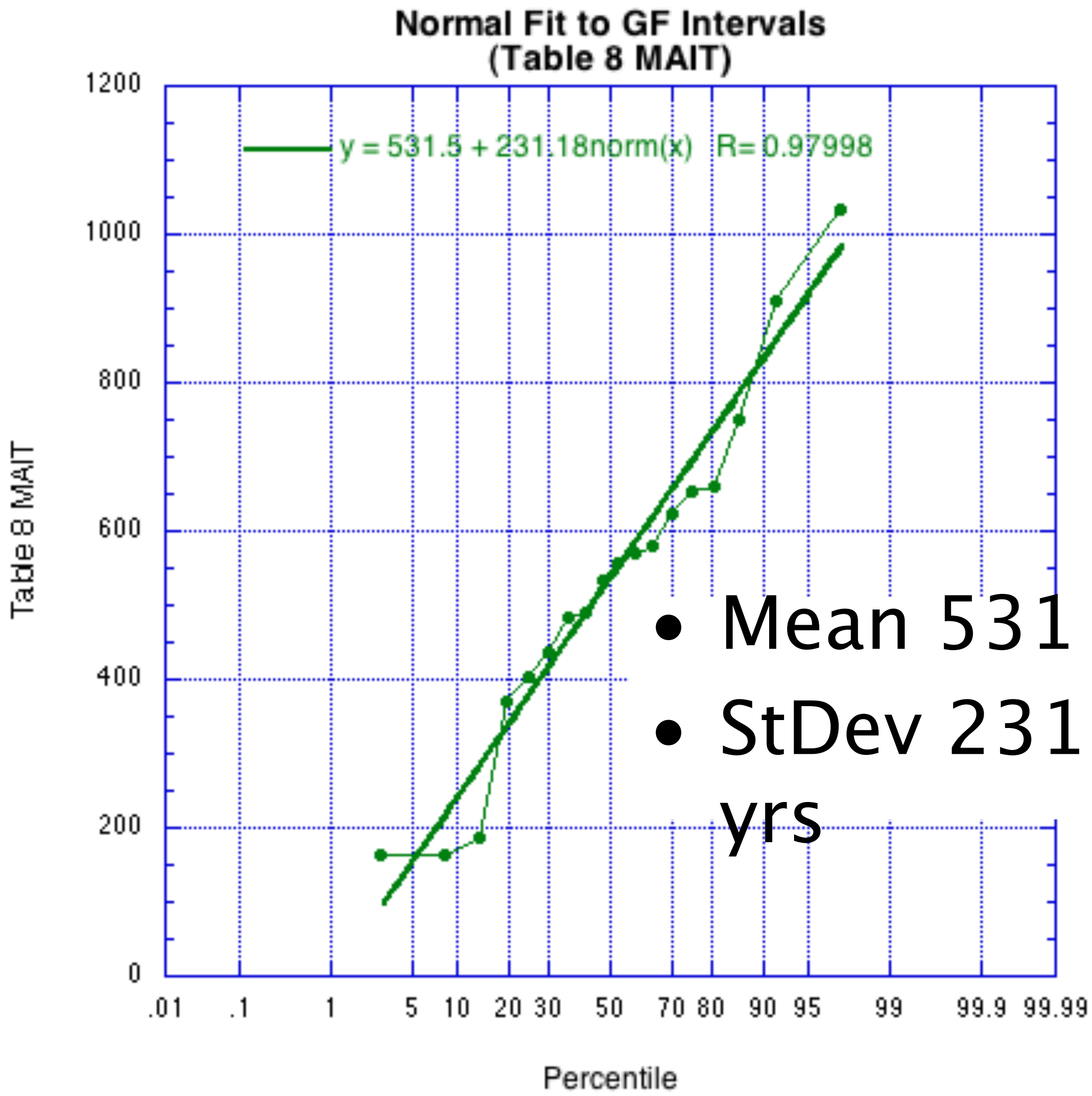
Topics Covered

- Gaussian fit to Northern Margin intervals (presumed full-length Cascadia rupture)
- Conditional probabilities for Nn and Sn Margin events in next 50 years
- Likelihood of clustering for random events
- Likelihood of clustering for events with uncertain dates
- Bayesian likelihood that clustering is real

Cumulative Gaussian Fit and Observations

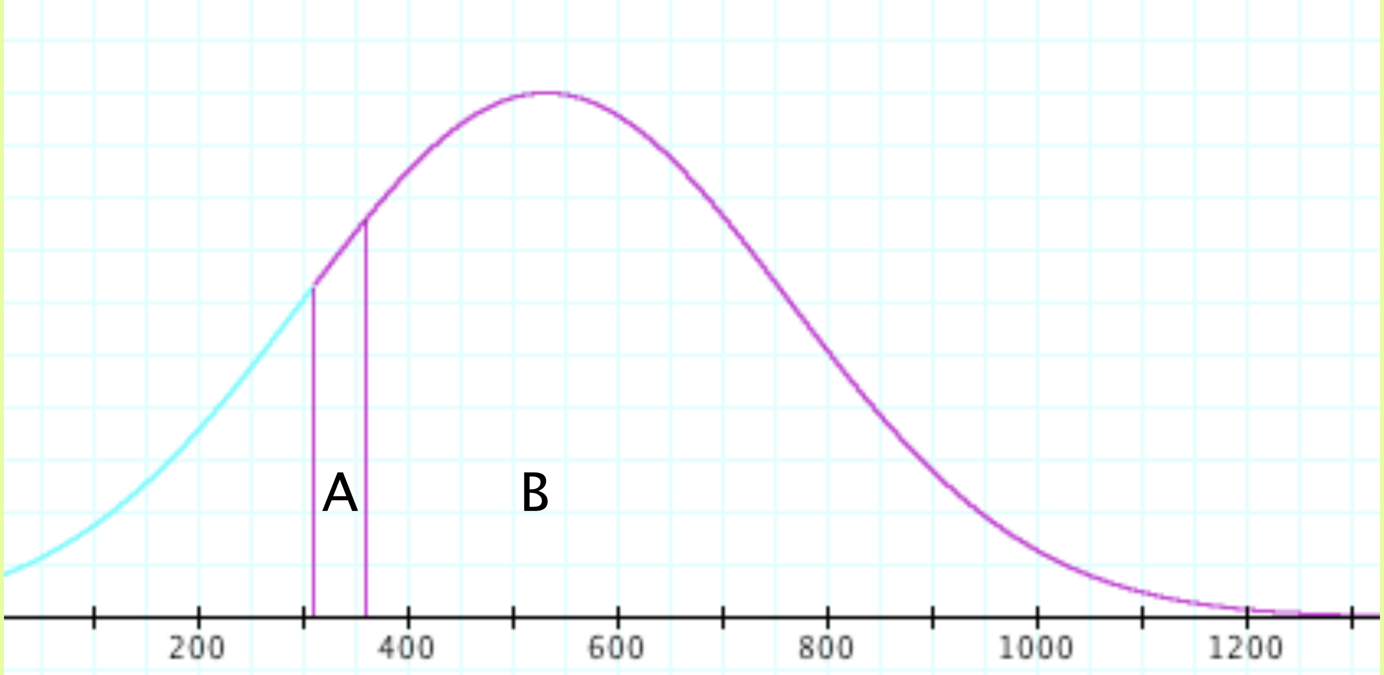


Gaussian Fit to Nn Intervals



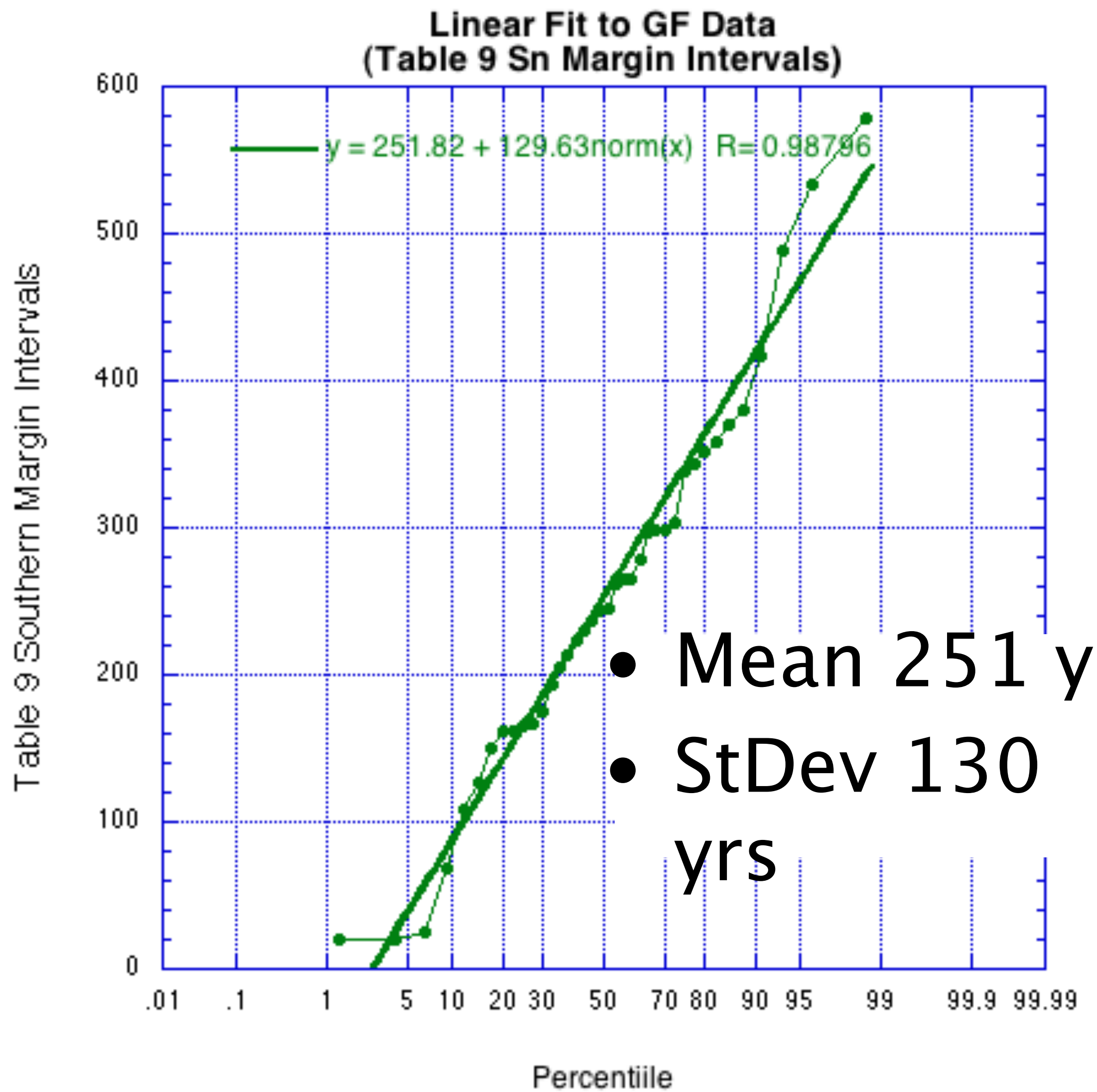
- Mean 531 yrs
- StDev 231 yrs

Conditional Probability for occurrence in next 50 yr



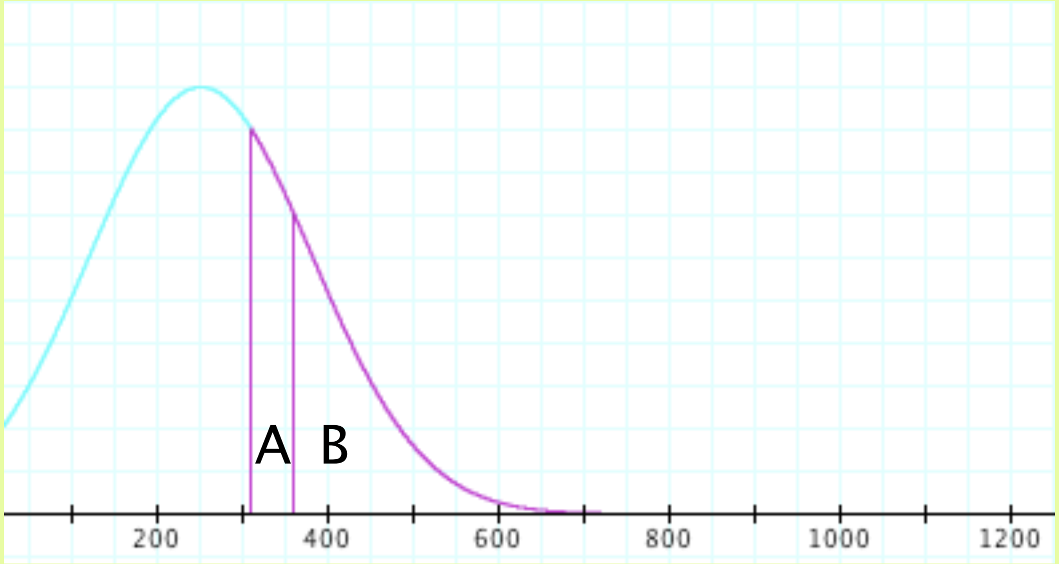
$$\frac{P(t > 310yrs) - P(t > 360yrs)}{P(t > 310yrs)} = \frac{A}{A+B} = 0.08$$

Gaussian Fit to Sn Intervals



- Mean 251 yrs
- StDev 130 yrs

Conditional Probability for occurrence in next 50 yr



$$\frac{P(t > 310yrs) - P(t > 360yrs)}{P(t > 310yrs)} = \frac{A}{A+B} = 0.38$$

Can clustering occur in random sequences?

- Test in three ways:
  1. Generate synthetic sequences of Gaussian intervals. Find clusters one of two ways:
     a. Find largest gap, next largest gap, until n or n+1 gaps have been recognized.
     b. Find largest gap, next largest gap, until current gap is not larger than mean + k*sigma of the remaining intervals.

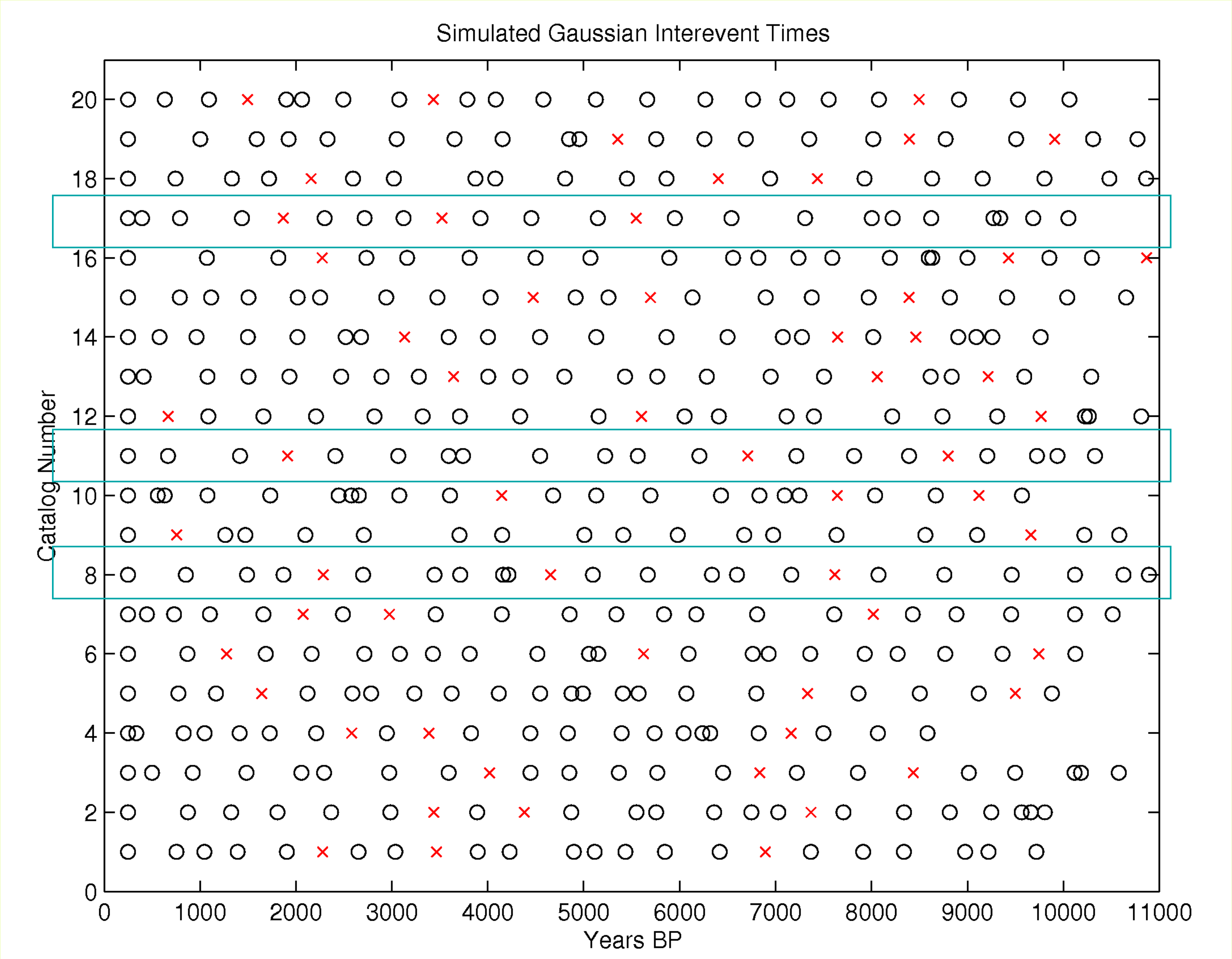
Generate random sequences

(Easier alternative methods:)

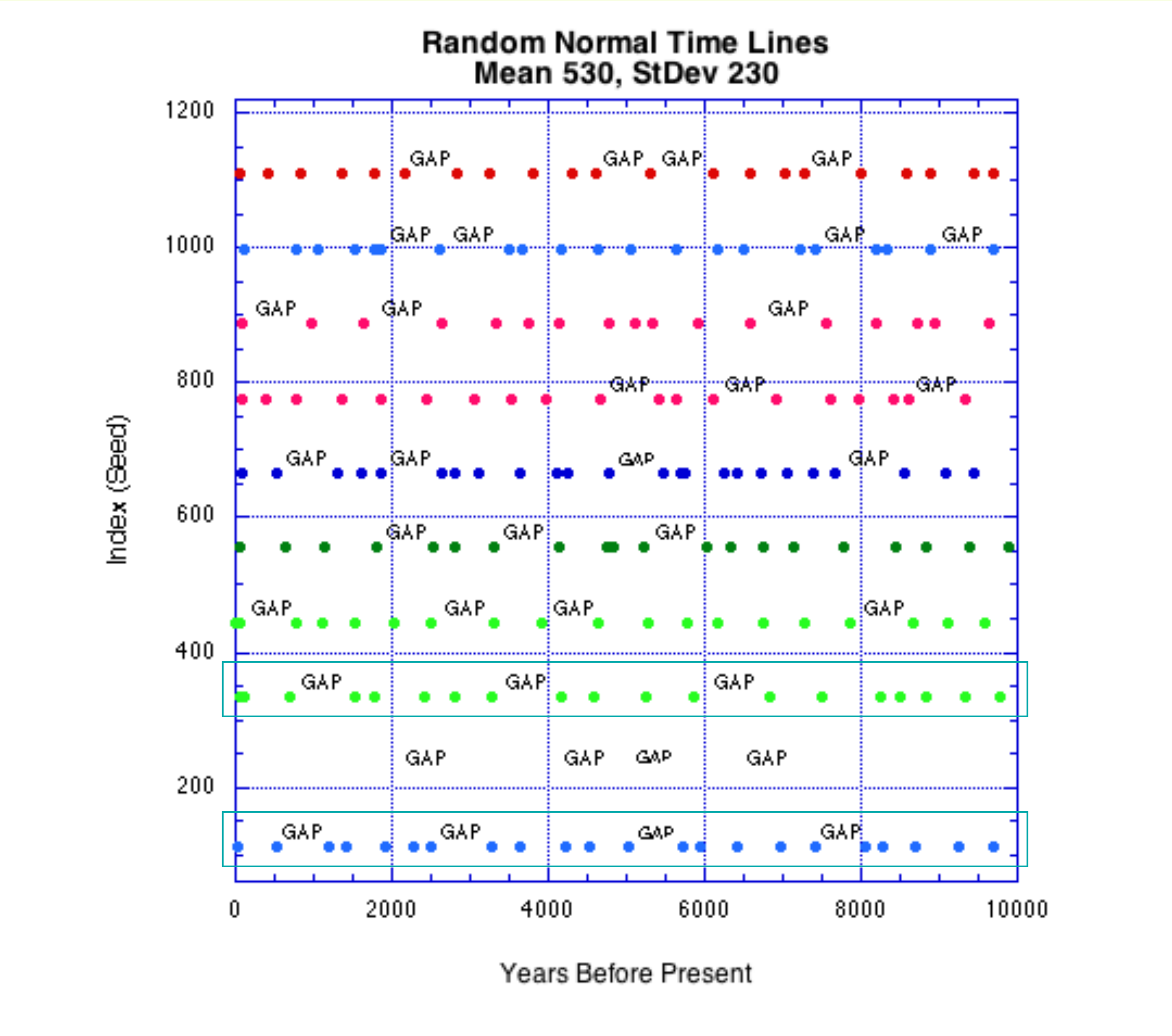
2. Generate sequences of large and small intervals, p(large) = 3/19, p(small) = 16/19
   ("sampling with replacement")
3. Randomly shuffle the observed (nominal) intervals ("sampling without replacement"). Guarantees 3 large, 16 small intervals.

Is the random sequence clustered similar to nominal pattern?

- Examine the pattern of gaps and clusters.
- Look for clusters with similar numbers of events and more or less evenly-spaced gaps.



Simulated Gaussian Interevent Times
Catalog Number
Years BP
0
2
4
6
8
10
12
14
16
18
20
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000


Random Normal Time Lines
Mean 530, StDev 230
Index (Seed)
Years Before Present
GAP
0
2000
4000
6000
8000
10000
200
400
600
800
1000
1200

50 Shuffles

Considered Clustered (9/50)	Considered Not Clustered (41/50)
cGccccccGcccccGccc	ccGcccGccccccccccG
cccccGcccGcccGcccc	cccccccGGcccccccGc
cGccccccccGcccccGc	cccGGcGccccccccccc
cccGccccGcccccccGc	GGcccccccccccGcccc
GcccccGcccccGccccc	ccGcccccccccccGcGc
GccccGccccGccccccc	ccccccccccccGGcccG
ccGcccccccccGccccG	cGccccGccccccccccG
ccGccccGcccccGcccc	cGccccccccccGccccG
ccGccccccGcccccccG	ccccGGcccccccccccG

Status of the Actual Sequence

It appears to be clustered and really is clustered
OR

It appears to be clustered and really is random

We have the result that 15 – 20 percent of the time a random sequence of 19 intervals over 10,000 years appears to be clustered.

Bayesian Estimate

Let RC = Really Clustered

Let RR = Really Random

Let AC = Appears to be Clustered

Let NC = Appears Not to be Clustered

Then

$$P(RC \mid AC = \frac{P(AC \mid RC)P(RC)}{P(AC \mid RC)P(RC) + P(AC \mid RR)P(RR)}$$

Needed Values

- P(RR) and P(RC) are complementary priors. If we are indifferent,

  $$P(RR) = P(RC) = 0.50$$

  If we doubt clustering, a priori, let

  $$P(RR) = 0.75 \text{ and } P(RC) = 0.25$$

- $P(AC|RR) = 0.20$
- We need $P(AC|RC)$

P(AC|RC)

To assess this probability, we need a sequence that is clearly clustered, but with uncertain dates. We take the nominal pattern to be this. Kulkarni and others obtained 20 sequences of new dates by sampling in the date uncertainties of the nominal pattern.

P(AC|RC) (continued)

We clustered those 20 according to method 1(a), finding 13 of the 20 would not have suggested the nominal clustering pattern.

We claim this as an estimate that a real cluster might appear unclustered given date uncertainty. Hence, P(AC|RC) = (20–13)/20 = 7/20 = .35

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P(Really Clustered)

Under the indifferent prior,

P(RC|AC) = (0.35*0.5)/ [(0.35*0.5)+(0.20*0.5)] = 0.64

Under the doubting prior,

P(RC|AC) = (0.35*0.25)/ [(0.35*0.25)+(0.20*0.75)] =

0.37

Conclusions

Intervals between events can be fit with a Gaussian distribution.

In the next 50 years,

the probability of a megathrust event on the Northern Margin is about 8% (less than the Poisson probability) and on the Southern Margin almost 40% (about double the Poisson probability)

Clustering behavior on the Northern Margin is very credible.

Addenda

Results using a Brownian Passage Time model are also very similar (.12 Nn, .34 Sn).

Addenda (continued)

Global survey of subduction zone behavior may improve P(RC) estimate

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