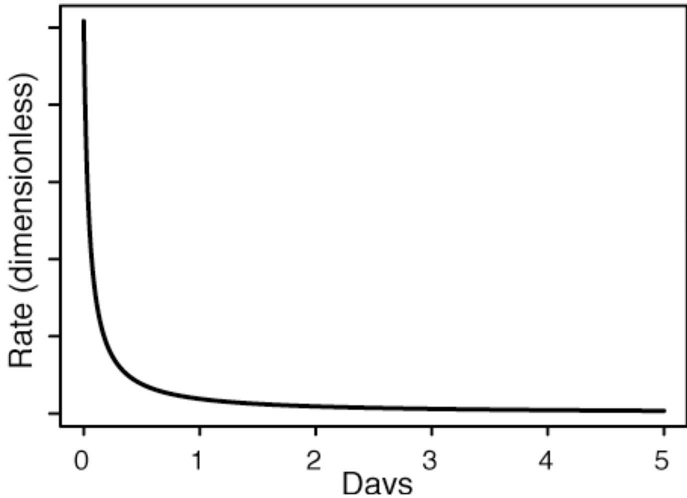
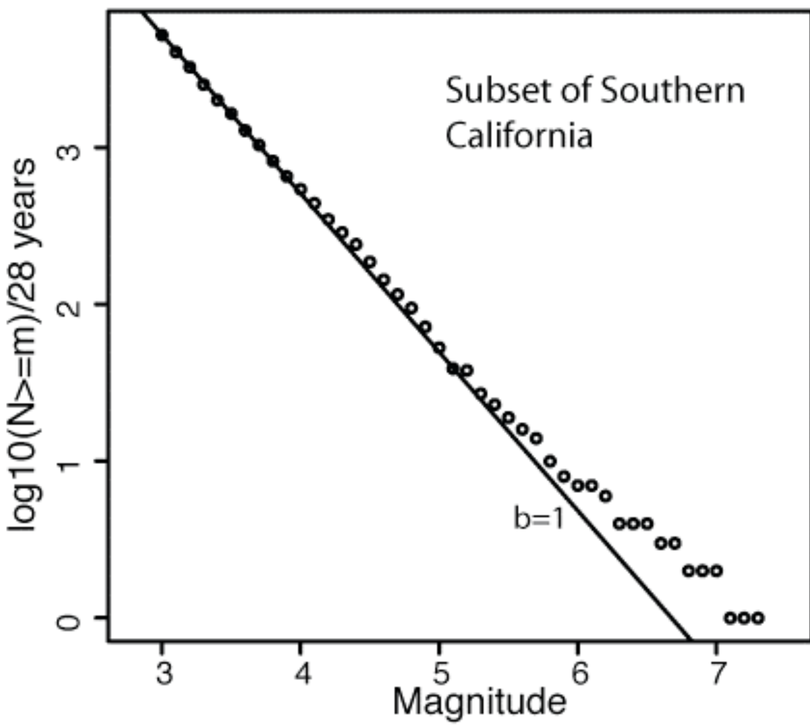
Model 1: Reasenberg and Jones, Science, 1989





Probability of earthquakes during an aftershock sequence as a function of time and magnitude.

Same ingredients used in STEP and ETAS

Model 2: Agnew and Jones, JGR, 1991

After discarding aftershocks,
earthquakes are divided into three categories for statistical purposes:

Mainshocks: which we want to forecast
Foreshocks: which are always followed by mainshocks
Background Events: which are never followed by mainshocks

When a moderate event occurs we can't tell if it is
a **foreshock** or a **background** event.

We calculate the probability that it is a **foreshock** by

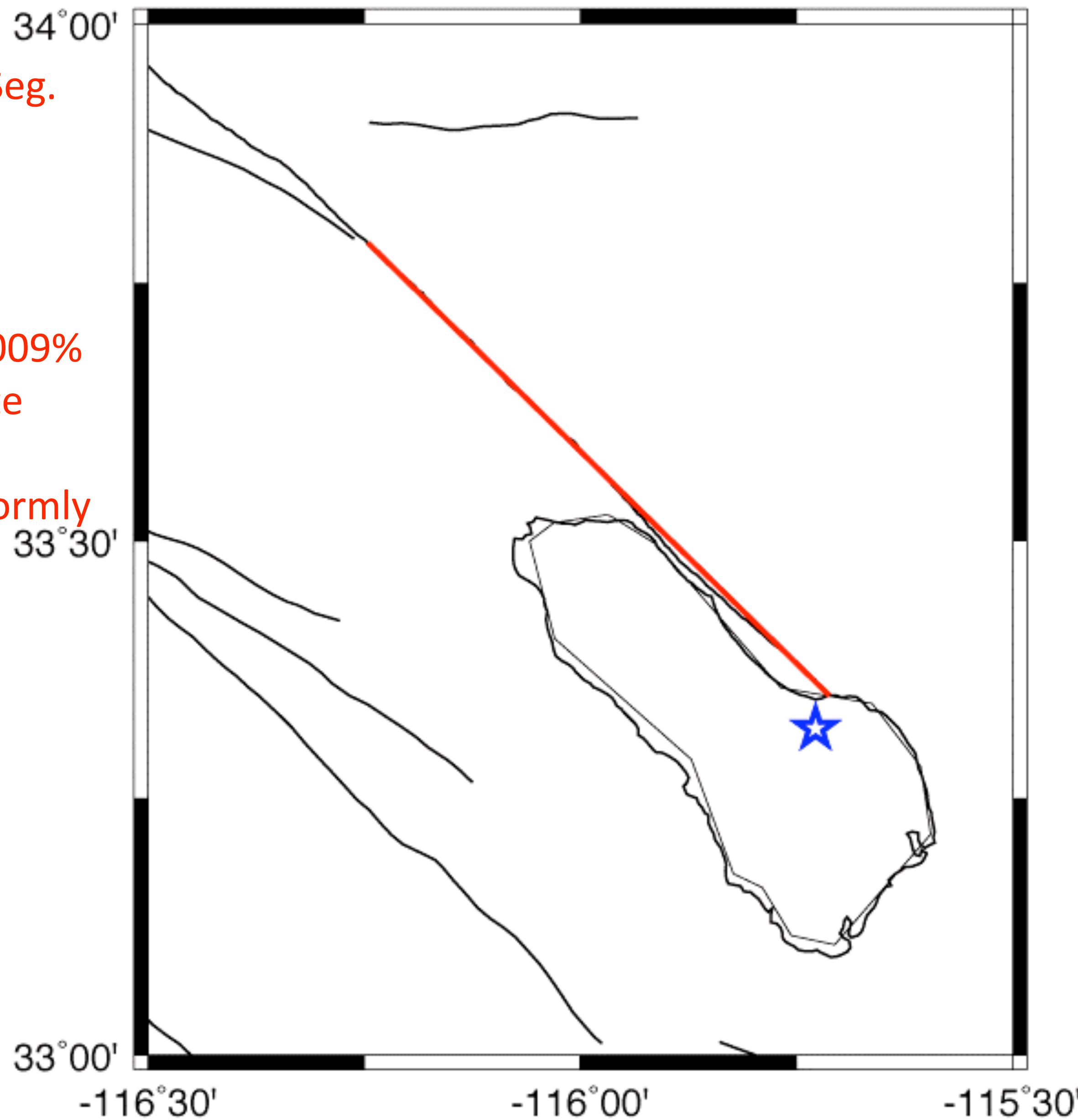
$$PF = \frac{\text{Rate of } \textbf{Foreshocks}}{\text{Rate of } \textbf{Foreshocks} + \text{Rate of } \textbf{Background Events}}$$

Rate of **Foreshocks** =
Rate of **Mainshocks** * Probability of **Foreshocks** Before **Mainshocks**

Need these rates over the area of interest.

M4.8 Event At Bombay Beach On March 24, 2009
Could It Be A Foreshock To A Larger Earthquake In The Next 3 Days?

Mainshock:
SAF, Coachella Seg.
UCERF2:
Length = 69 km
M 7
5-yr Prob. = 5%
3-day Prob.= 0.009%
1-yr Poisson Rate
= 0.011
Nucleation uniformly distributed along segment



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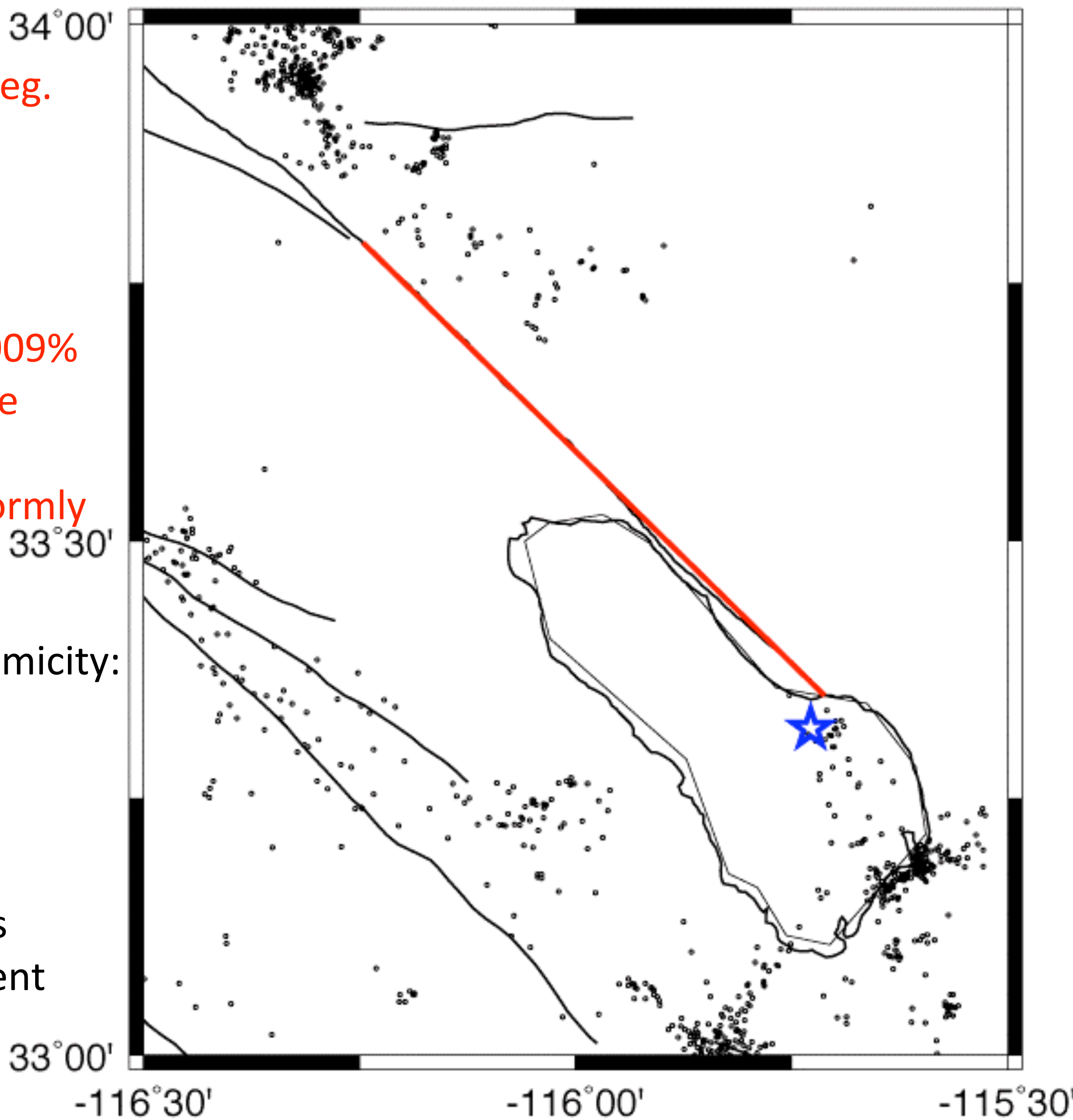
Background Seismicity:
M≥ 3
1981 – 2008

Declustered by removing events with a larger event in the previous 3 days.



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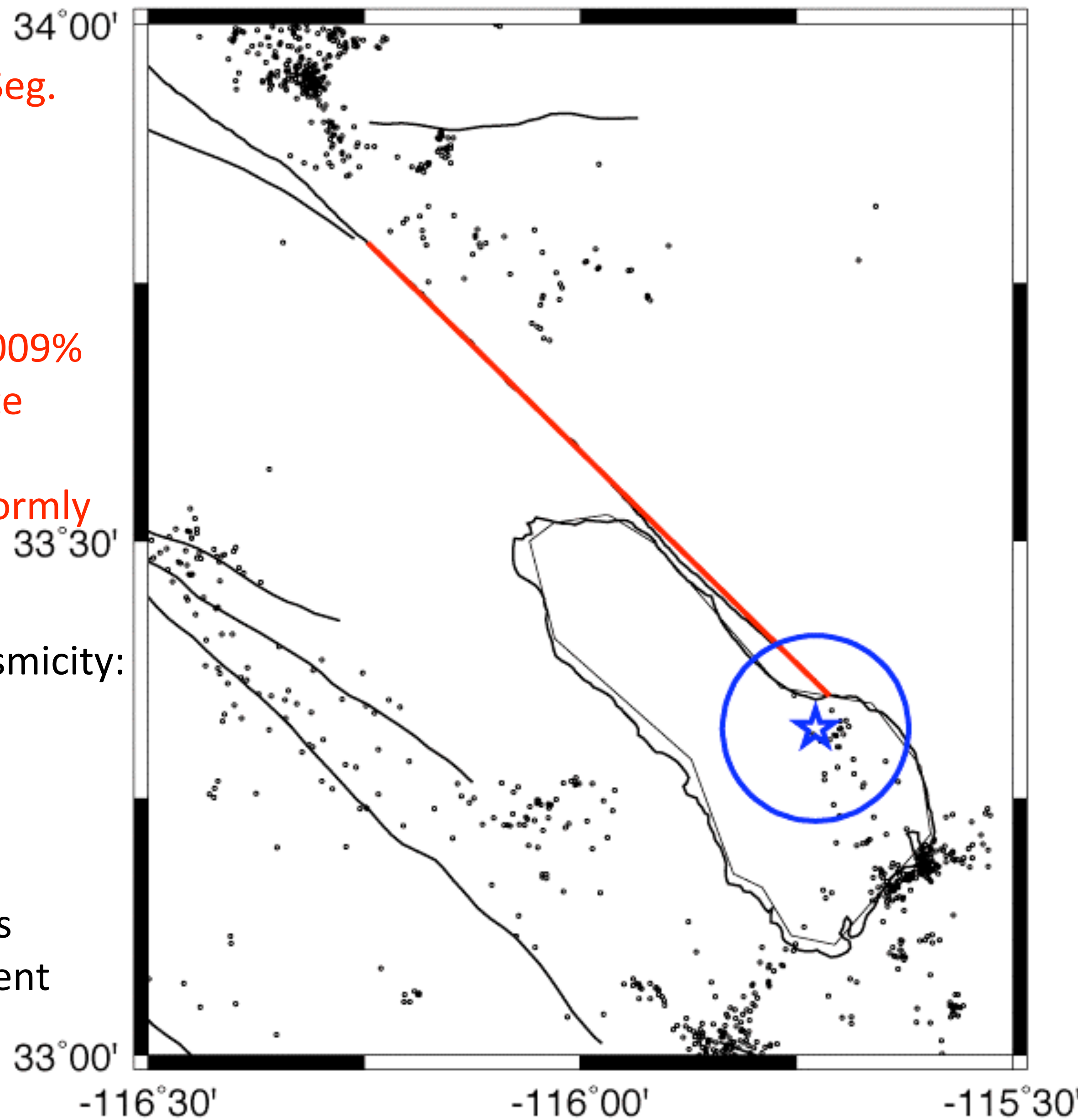

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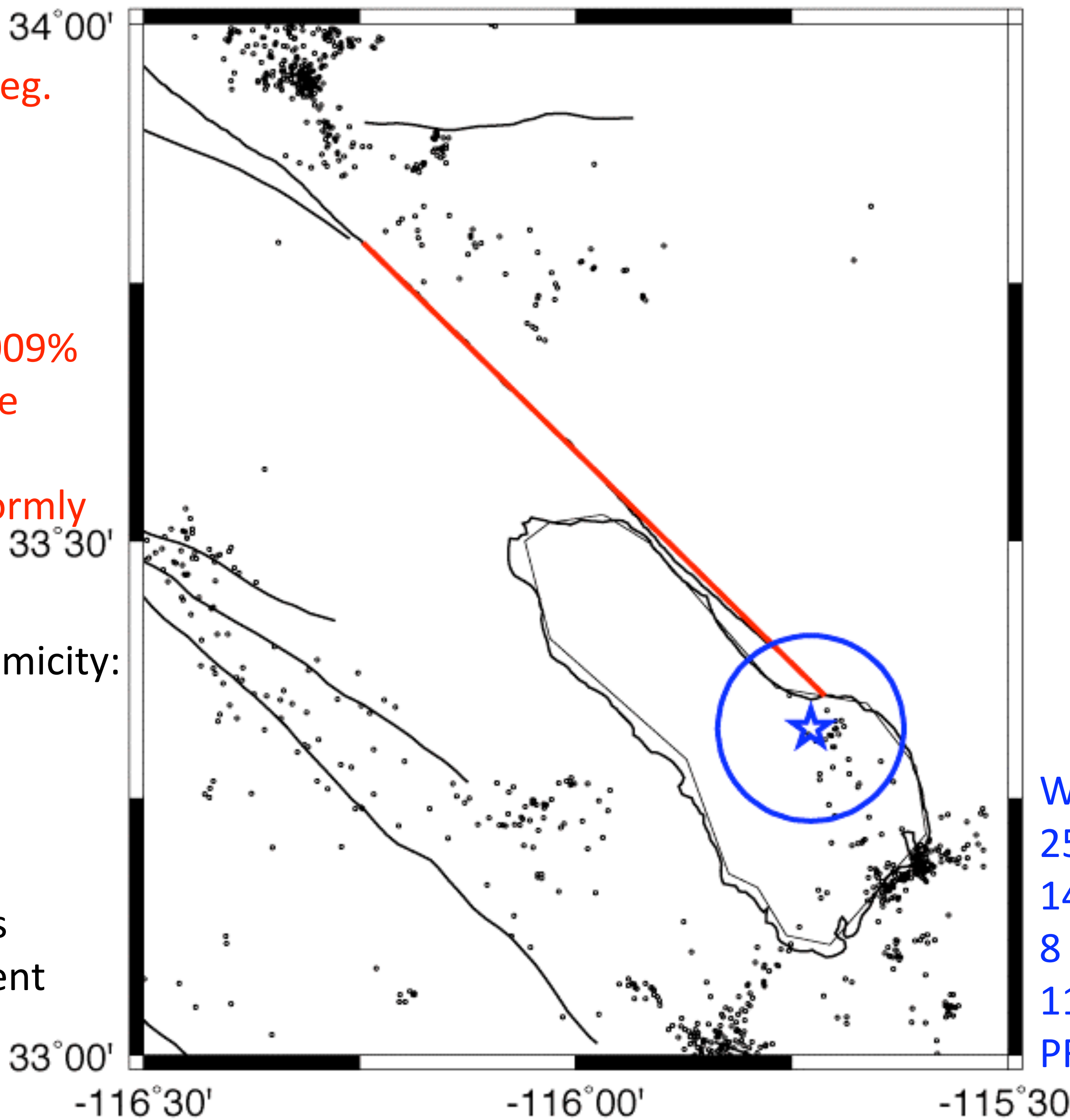
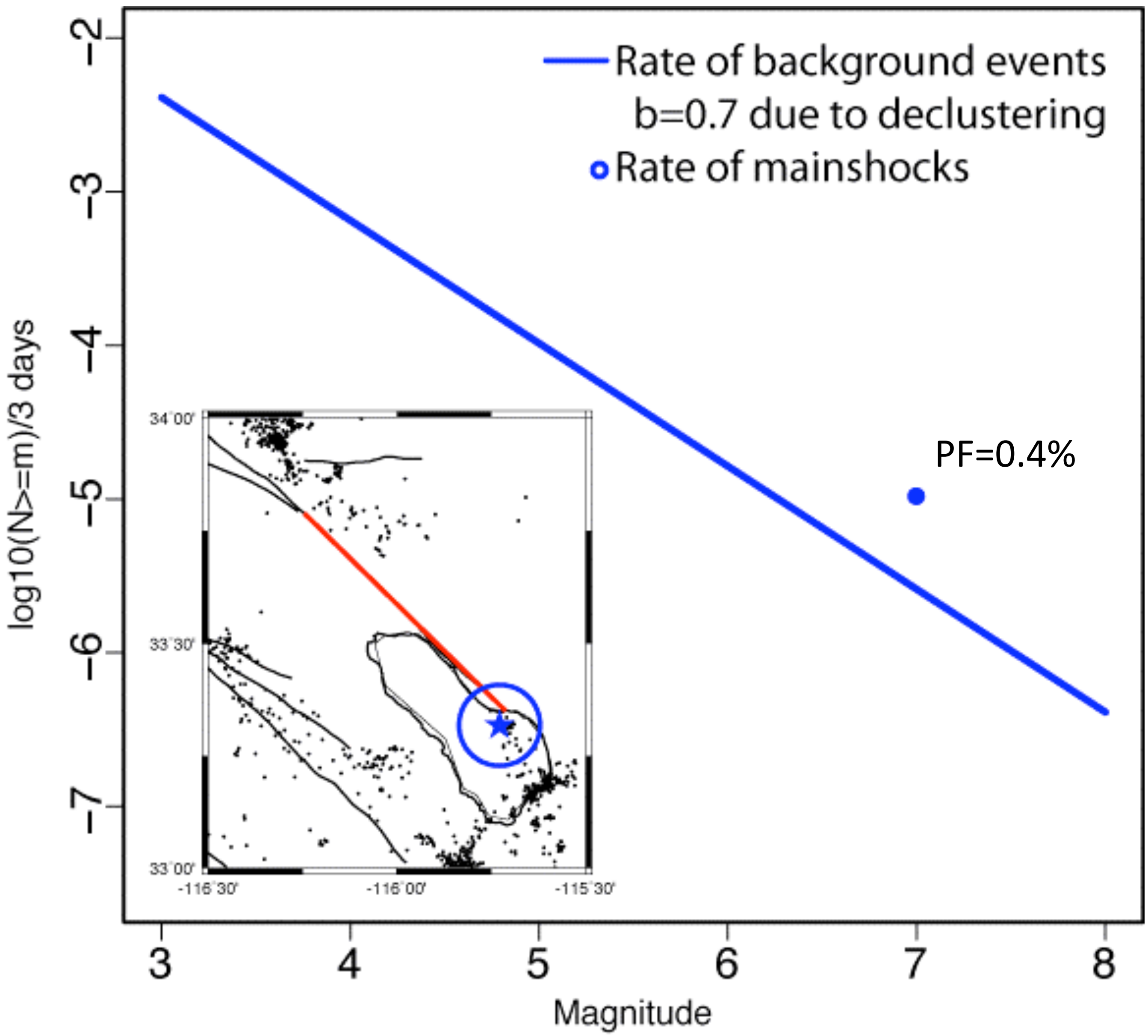


Within 10 km:
25 Background Events
14 After Declustering
8 km of Fault Segment
11% of Fault Segment
PF = 0.4%

Earthquake Rates Are Not Gutenberg-Richter In The Circle



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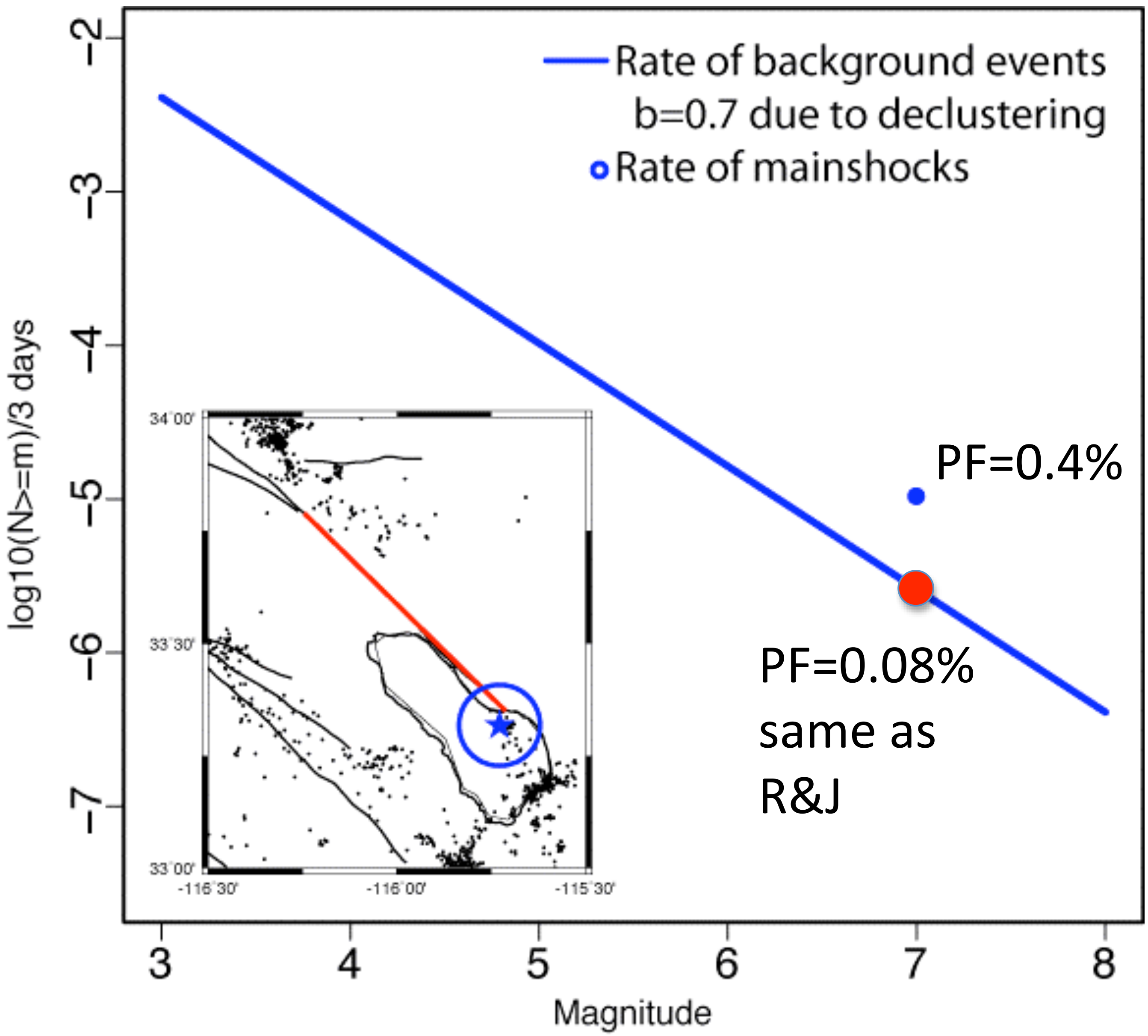


Uncertainties for March 24 Bombay Beach Event

Case	Probability Of Being A Foreshock
Best Estimate	0.4%
Mainshock Probability from 1.2% to 31% / 5 years (UCERF2 Min to Max)	0.09% to 4%
Mainshock Nucleation Allowed Only At Segment Endpoints	2%
Mainshock Probability of 31%/5 years and Nucleation Allowed Only At Segment Endpoints	15%
Candidate Event Magnitude from 4.6 to 5.0	0.3% to 0.6%
Number of Background Events from 7 to 24 (Poisson 95% Confidence Limits)	0.2% to 0.8%

Untreated Uncertainties (all relatively minor):

- Location of Candidate Event which effects length of mainshock and number of background events in circle.
- Mainshock segment endpoints which affects length of mainshock in the circle.
- Foreshock rate w.r.t. time and distance but it is estimated over many sequences and so known fairly well as compared to other parameters.
- b-value of background events and long-term temporal variations in the background event rate.

Summary

Agnew and Jones reduces to standard clustering models (e.g. Reasenberg & Jones, ETAS) if the world is Gutenberg-Richter with constant b-value or proportional frequency-magnitude shape.

Applicability of the Agnew and Jones model depends on our conclusions about Gutenberg-Richter behavior over small scales.

Could fold more complex frequency-magnitude behavior into standard clustering models and unify foreshock and aftershock models.

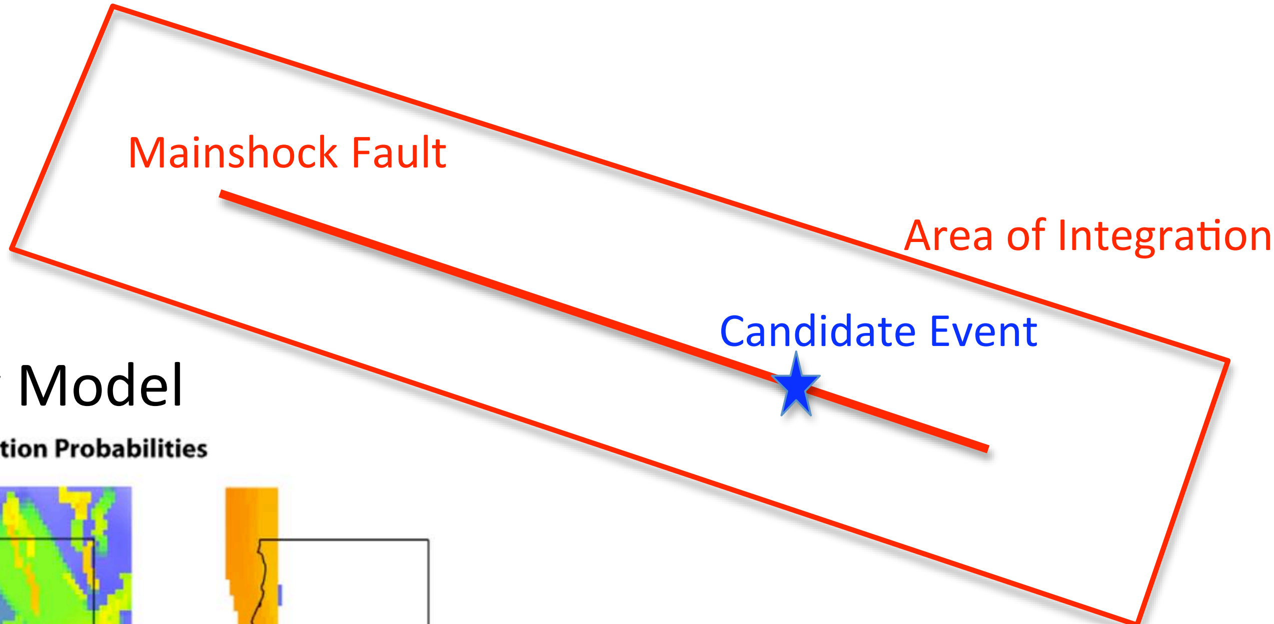
The Agnew and Jones model is very sensitive to the mainshock rate model and so any prospective test will largely be a test of the mainshock model such as UCERF2.

Any short duration test will largely test the model at small magnitudes and thus will not really test UCERF2.

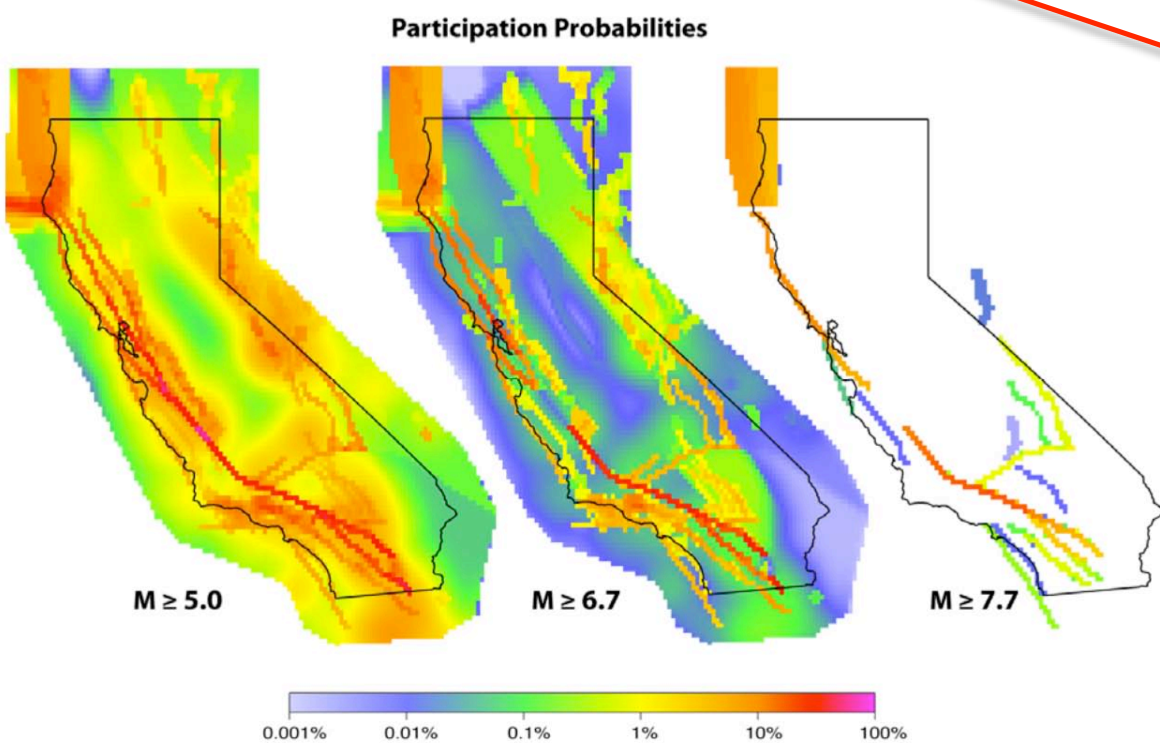
Testing the complete model prospectively may not be the most effective approach. Instead we should test the ingredients.

Implementation of Agnew and Jones Model

1991 Implementation: Characteristic Mainshocks on Segments



UCERF2 Probability Model



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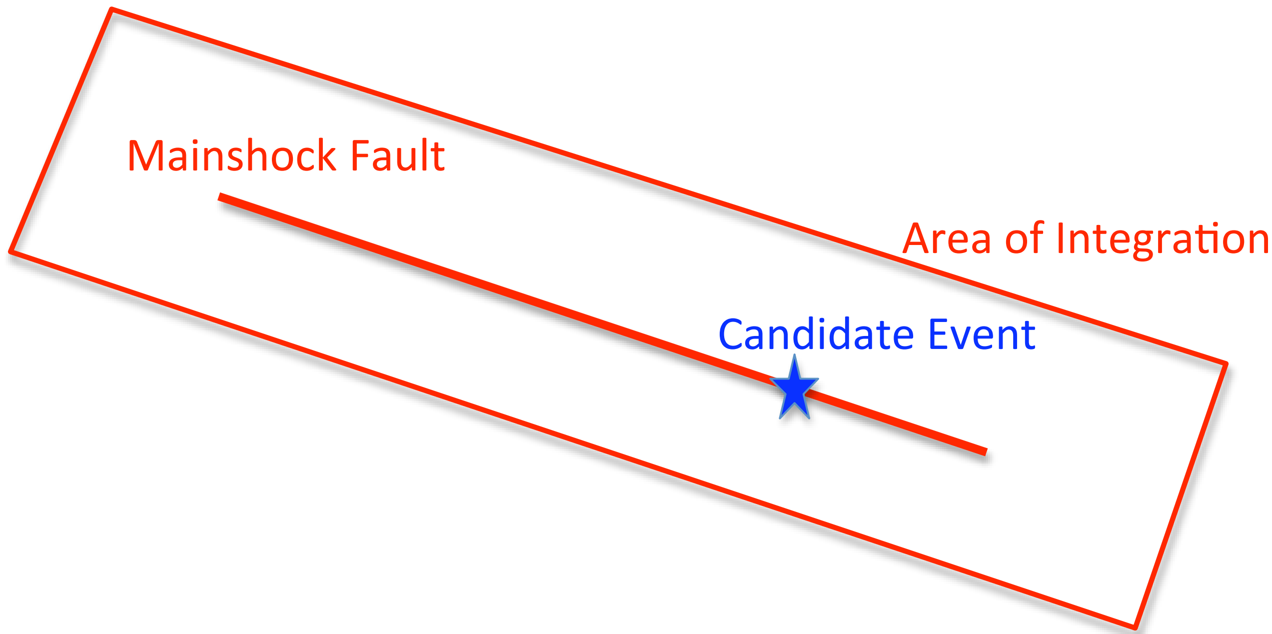
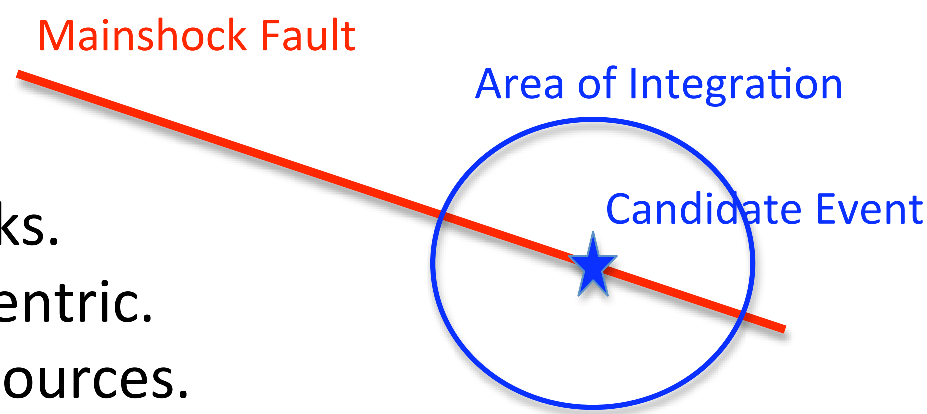


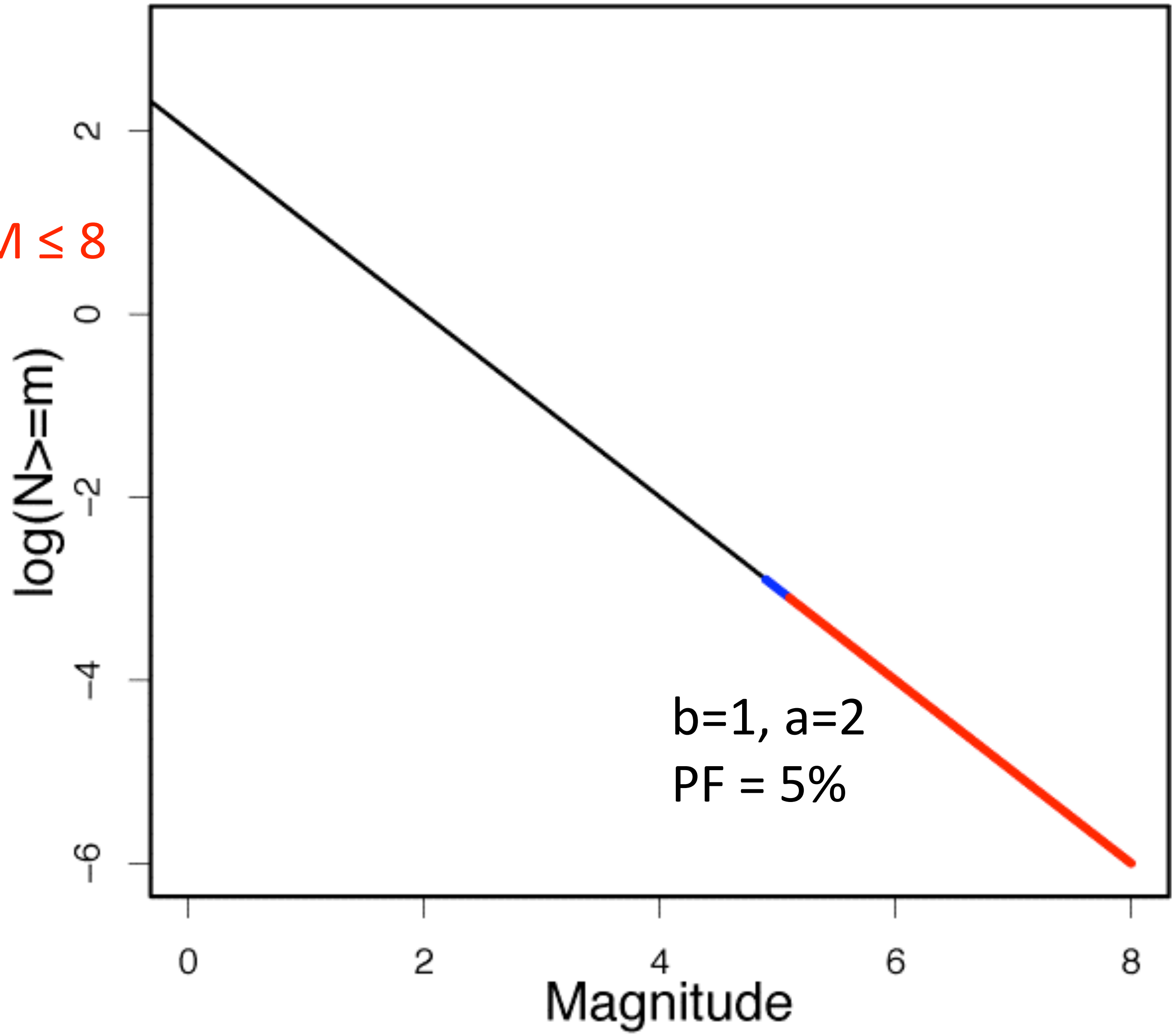
Updated Implementation:
Utilize current probability models such as UCERF2.
Add Gutenberg-Richter mainshocks.
Area of integration is candidate-centric.
Allows for multiple faults & area sources.



Agnew and Jones in a Gutenberg-Richter World

Candidate Event
M = 5 ± 0.1

Mainshock 5.1 ≤ M ≤ 8



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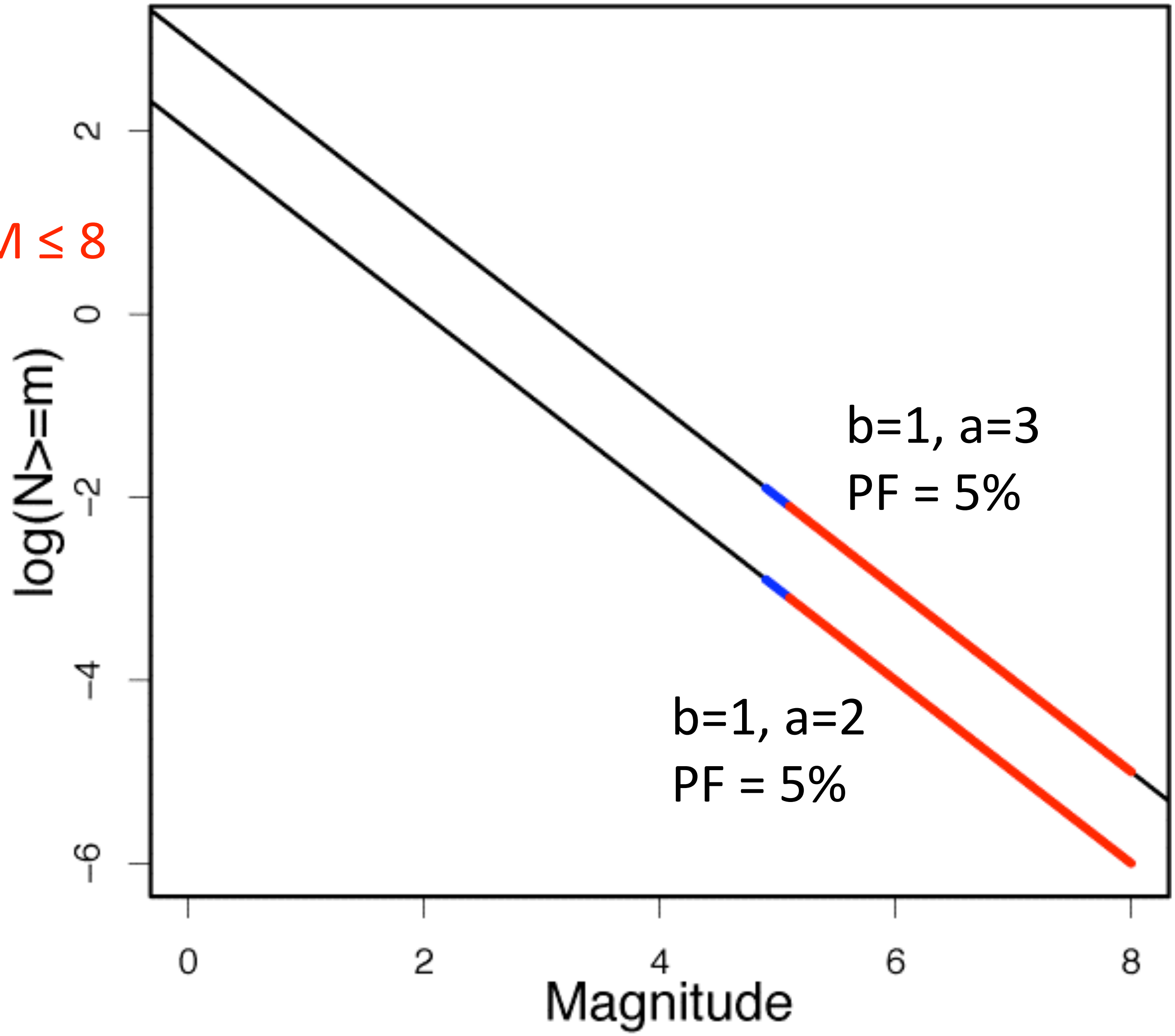

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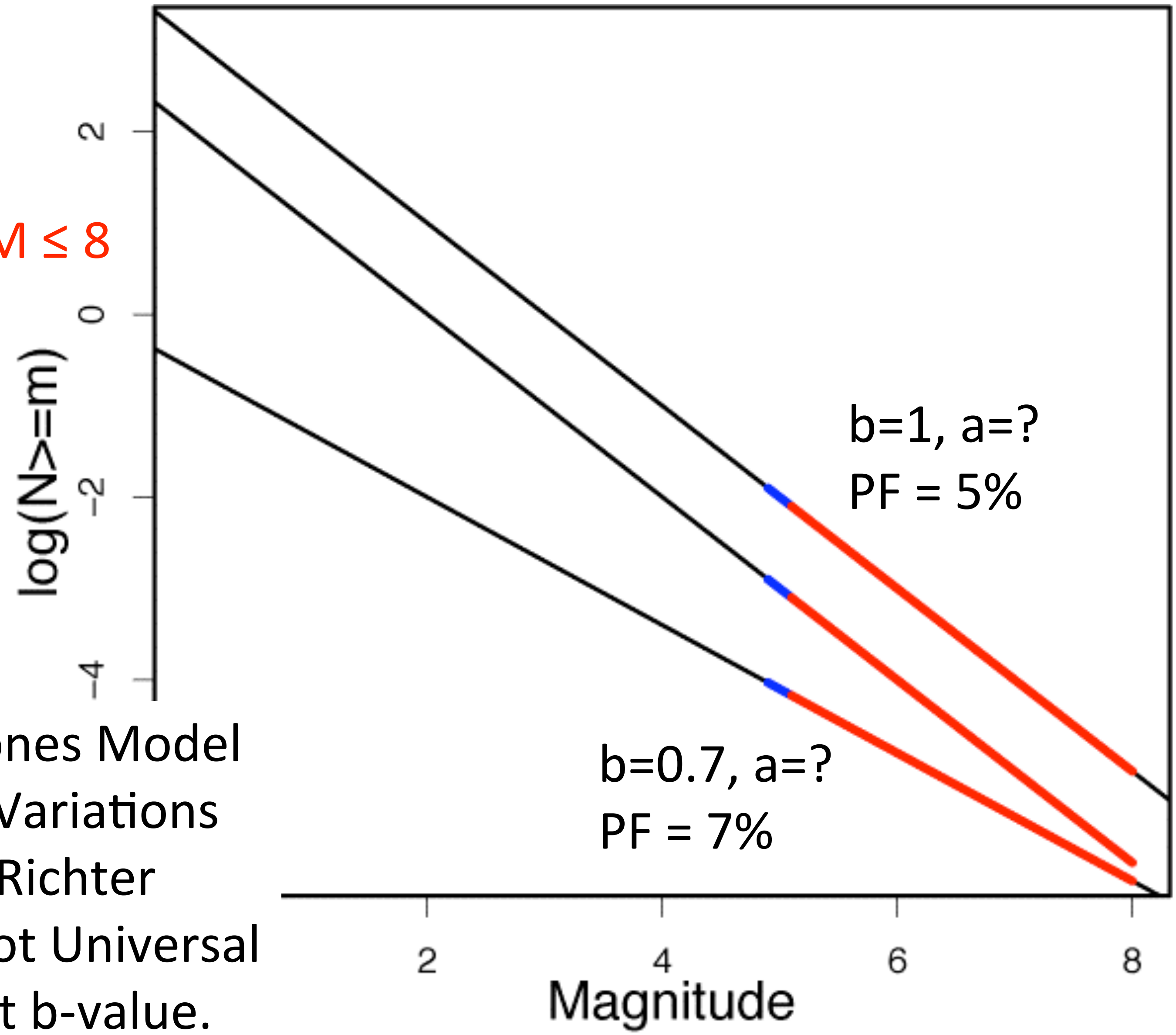

Agnew and Jones Model
Gives Spatial Variations
If Gutenberg-Richter
Behavior Is Not Universal
With Constant b-value.

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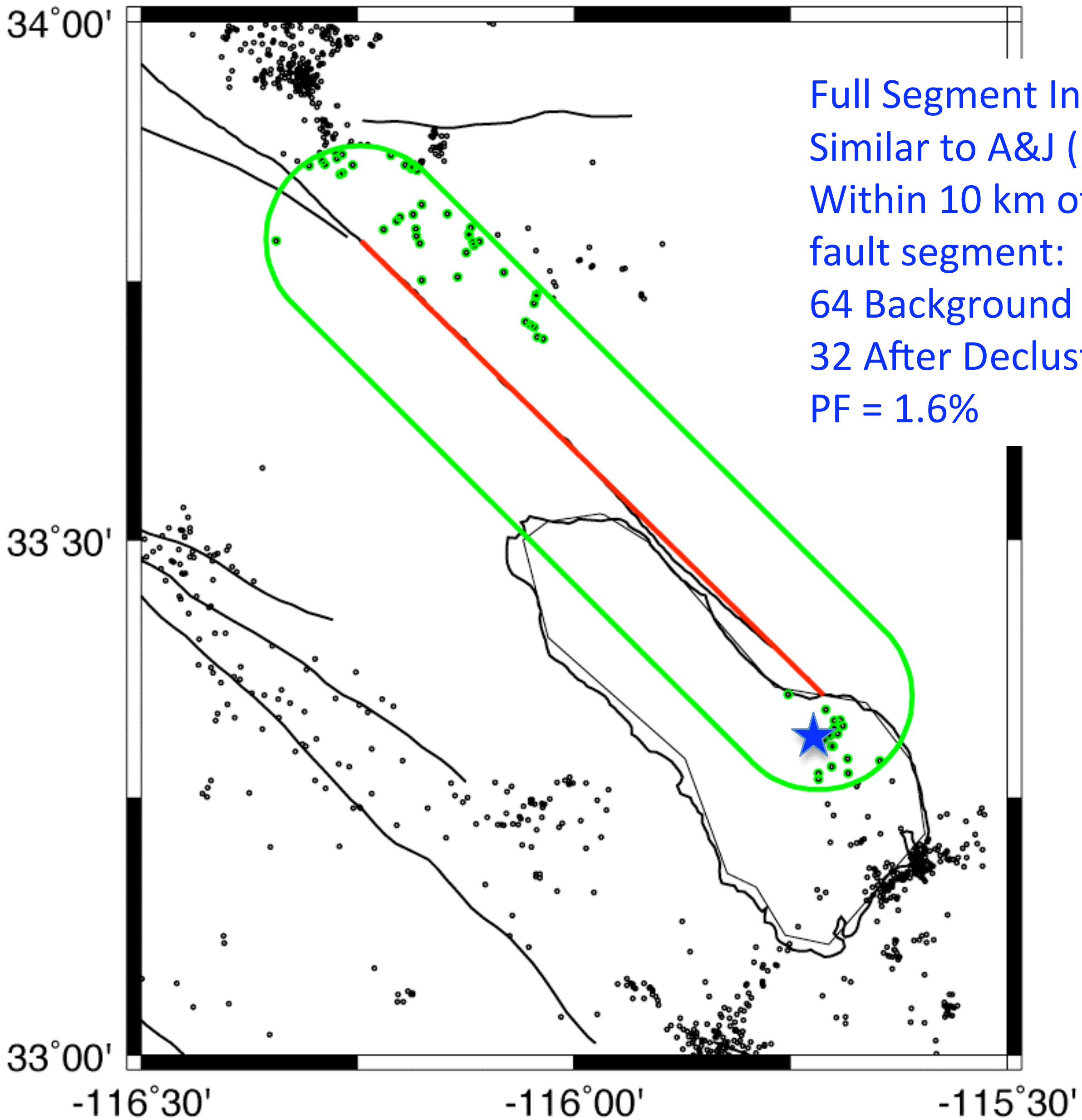

Full Segment Integration
Similar to A&J (1991)
Within 10 km of entire fault segment:
64 Background Events
32 After Declustering
PF = 1.6%

Earthquake Rates Are Not Gutenberg-Richter In The Circle or Entire Segment
Departure from Gutenberg-Richter Varies For Each Circle
Therefore Agnew and Jones Probabilities Vary