# Strategies for retrospective testing including STEP-variants

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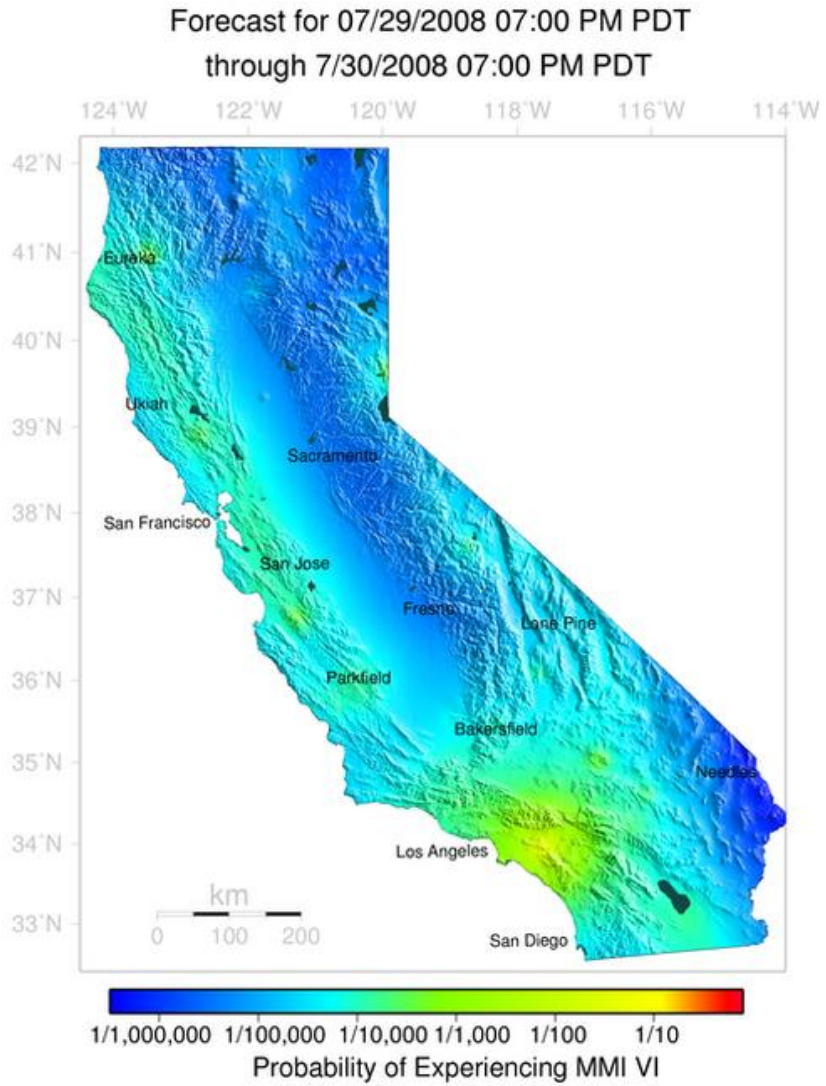

# Do Aftershock Probabilities Decay With Time?

Andrew J. Michael
USGS

May 18, 2012
In press, Seismological Research Letters

Urban planners divide disaster recovery into a series of overlapping stages:

(1)*Emergency* consisting of search and rescue, fire fighting, emergency shelters, and damage assessment;

(2)*Restoration* consisting of the restoration of utility services, debris removal, and temporary repairs to structures to make them usable for the short-term;

(3)*Reconstruction* during which structures are replaced to predisaster levels;

(4)*Betterment* during which major redevelopment projects improve the community to a new standard;

(5) the *Long-Term* future.

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Stages of Disaster Recovery and Aftershock Probabilities

| Stage | Dominant Time Period post-Mainshock | Probability of an Aftershock with $M_a \geq M_m - 1$ | | | Probability of an independent event with a rate of 0.01 events/year |
|---|---|---|---|---|---|
| | | RJ89 Generic Model, $p$=1.08 | RJ89 Generic Model modified to $p$=1 | Felzer, 2003, multi-window model, $p$=1.34 | |
| 1 - Emergency | 0 – 14 days | 61% | 61% | 35% | 0.04% |
| 2 - Restoration | 14 days – 1 year | 33% | 43% | 10% | 1% |
| 3 - Reconstruction | 1 – 3 years | 11% | 17% | 2% | 2% |
| 4 - Betterment | 3 – 10 years | 11% | 19% | 1% | 7% |
| 5 – Long-Term | 10 – 50 years | 13% | 24% | 1% | 33% |

# Smoothness is a double-edged sword

- STEP is “better” than ETAS because STEP is less smooth
- STEP fails S-test more frequently than ETAS because STEP is less smooth

From Jeremy Zechar’s talk

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# Advantages of ETAS

STEP is based on Reasenberg and Jones, *Science*, 1989
Starts forecasting based on generic sequence parameters
Updates the parameters when sufficient data is available, no earlier than 100 events.

ETAS is based on Ogata, J. Am. Stat. Assoc., 1988
Starts forecasting based on generic parameters
Updates as each earthquake is observed or time passes without an event
Can also update parameters when sufficient data is available.

ETAS should adapt to sequences faster than STEP.

Will only partially adapt without updating parameters because half or more of a sequence is a direct descendant of the initiating event.

So why is STEP doing better?

# Potential next steps

- See if complexities of STEP (sequence-specific parameterization, spatially-varying parameters) provide strong advantage
  - How often does STEP go into these modes?
- Re-analyze with updated data
- More splitting vs. lumping
- Bayesian analysis
- Construct ensemble forecasts

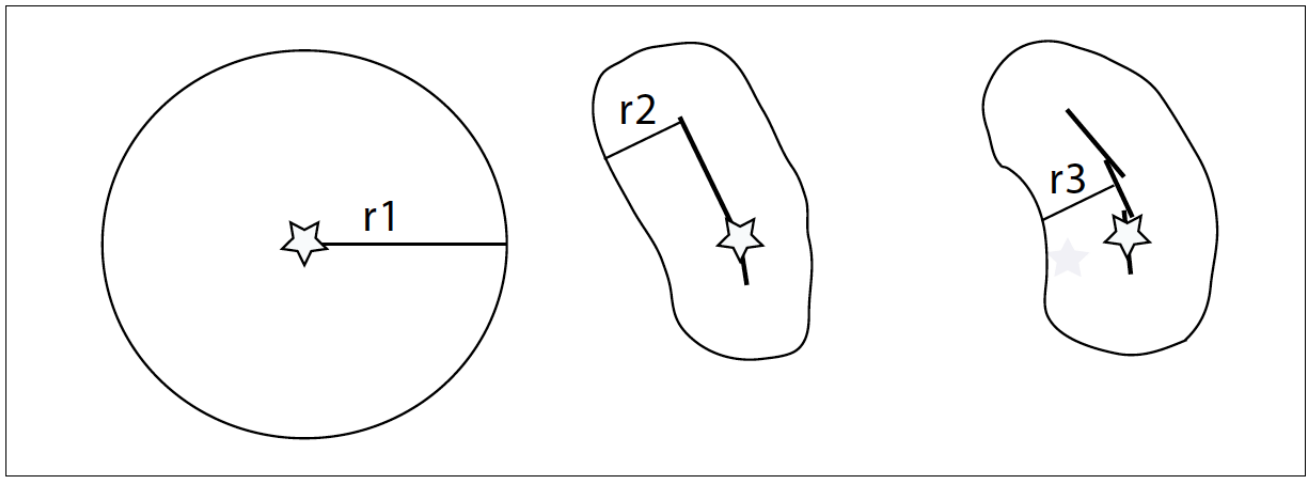
From Jeremy Zechar's talk

# Complexities of STEP

Initially use a circular aftershock zone with a generic Reasenberg and Jones rate model.

After 100 aftershocks are found, base aftershock zone on locations of aftershocks and sequence specific parameters are used, spatially varying sequence specific parameters are used if possible.

If a finite fault model is available, type 3 aftershock zone based on distance from the fault.



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# Complexities of STEP

Every event in a sequence plays two roles:

1) recalculation of the sequence specific parameters for the mainshock
2) produces its own secondary sequence (circular and generic)

To prevent double counting, in any spatial bin only the highest rate from either the mainshock or a secondary sequence is used in the forecast.

**STEP is pseudo-ETAS**

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# If STEP is pseudo-ETAS, then learn from it

ETAS is a more natural system than STEP.

As Jeremy suggested, turn on and off features in STEP to see how they affect the performance in retrospective tests, adopt the key features into ETAS models:

Sharper distance fall-offs?
Updated sequence specific parameters?
Fault-based aftershock regions?

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# Retrospective Testing Strategy For Optimized Models

When models are optimized based on the data it is hard to test them retrospectively if all of the data has been used in the optimization.

Better to use training and test data sets.

Also, reverse training and test data sets.

Problem: data quality changes with time so using early period as training and late period as testing may introduce problems by optimizing on data that isn't as good as the data used for the test.

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# Retrospective Testing Strategy For Optimized Models

Consider developing and testing a simple ETAS model.
Assume functional forms for temporal and spatial intensity functions.
Determine parameters from training data.
Test fit to test data.

Use non-contiguous training and test data sets.

E.g. Odd years are in training set (2001, 2003, 2005, 2007,…)
Even years are in test sets (2002, 2004, 2006, 2008, …)

Now data quality changes are similar for both training and test sets.

# Retrospective Testing Strategy For Optimized Models

Strategy 1:

Odd years are in training set (2001, 2003, 2005, 2007,…)

Even years are in test sets (2002, 2004, 2006, 2008, …)

Strategy 2:

Training set is all earthquakes but weighted by a smoothly varying function of time, e.g. $W_{training} = (1+\sin(t))/2$

Test set is all earthquakes weighted by $W_{test} = 1-W_{training}$

Now there are no sharp boundaries but key sequences could be heavily weighted in one set or the other.

Strategy 3:

Number earthquakes i=1, 2, 3, …. N

Odd earthquakes have $W_{training} = 1$, $W_{test} = 0$

Even earthquakes have $W_{training} = 0$, $W_{test} = 1$

Now all sequences are represented in both training and test data sets.

# Retrospective Testing Strategy For Optimized Models

If models can be set up as optimization procedures then we can test retrospectively in a meaningful way.

Meaningful retrospective tests could lead to faster adoption of models in OEF while also doing prospective tests.

If a model can't be set up as an optimization procedure then it might have to wait for validation in a prospective test which will be a much slower procedure.

Can we set up our models as optimization procedures?