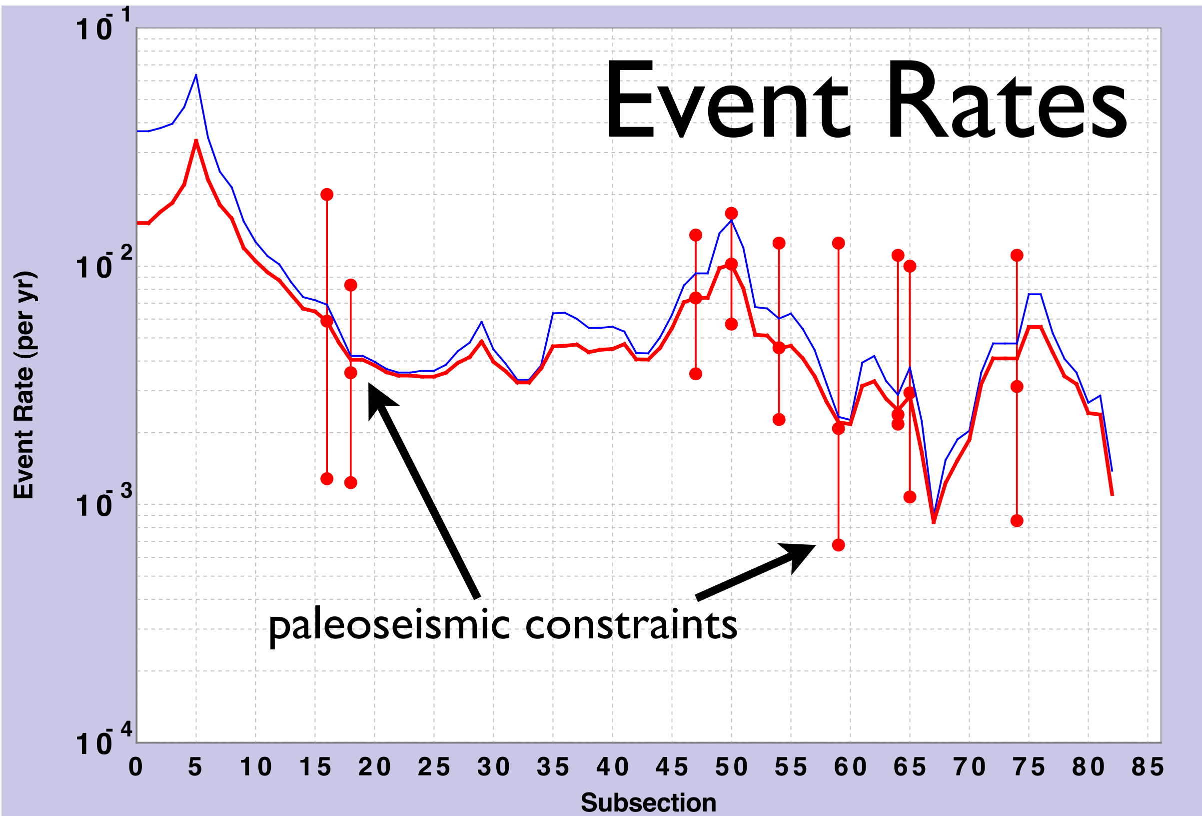
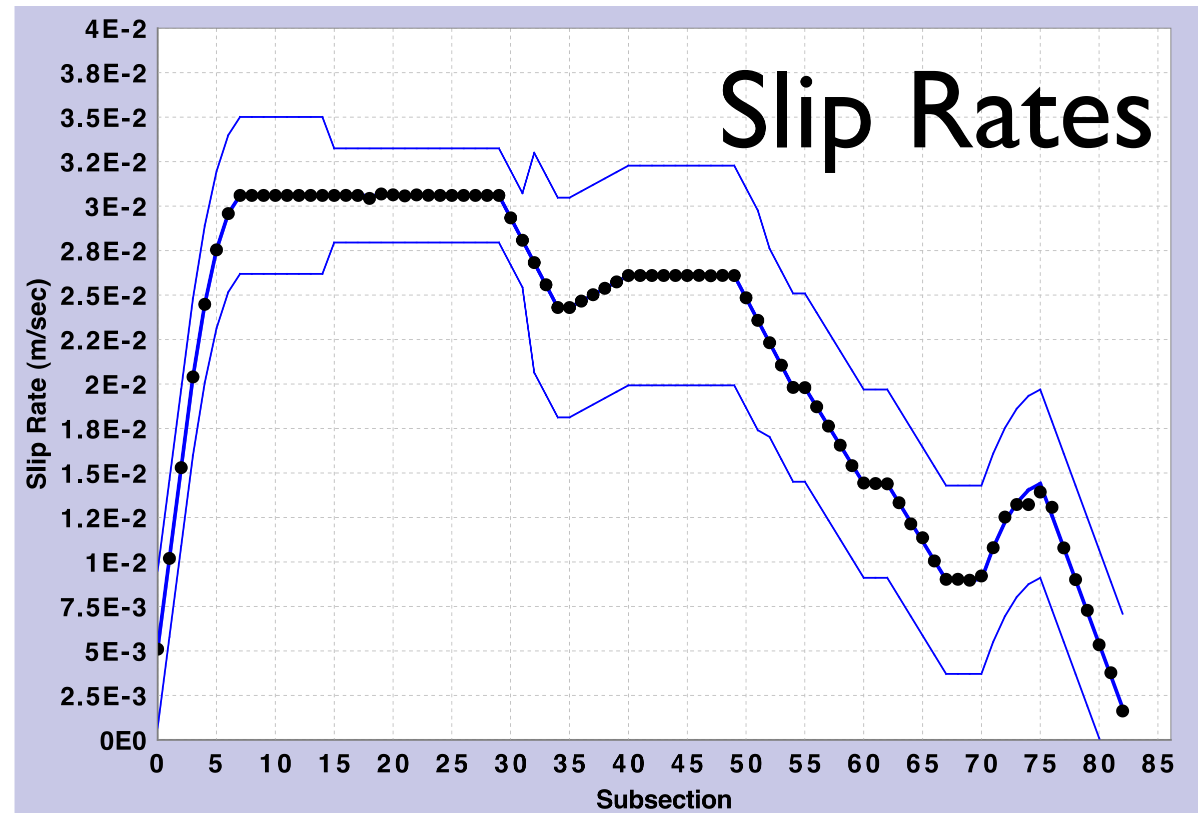
A Generalized Inverse Approach
(Part 2)



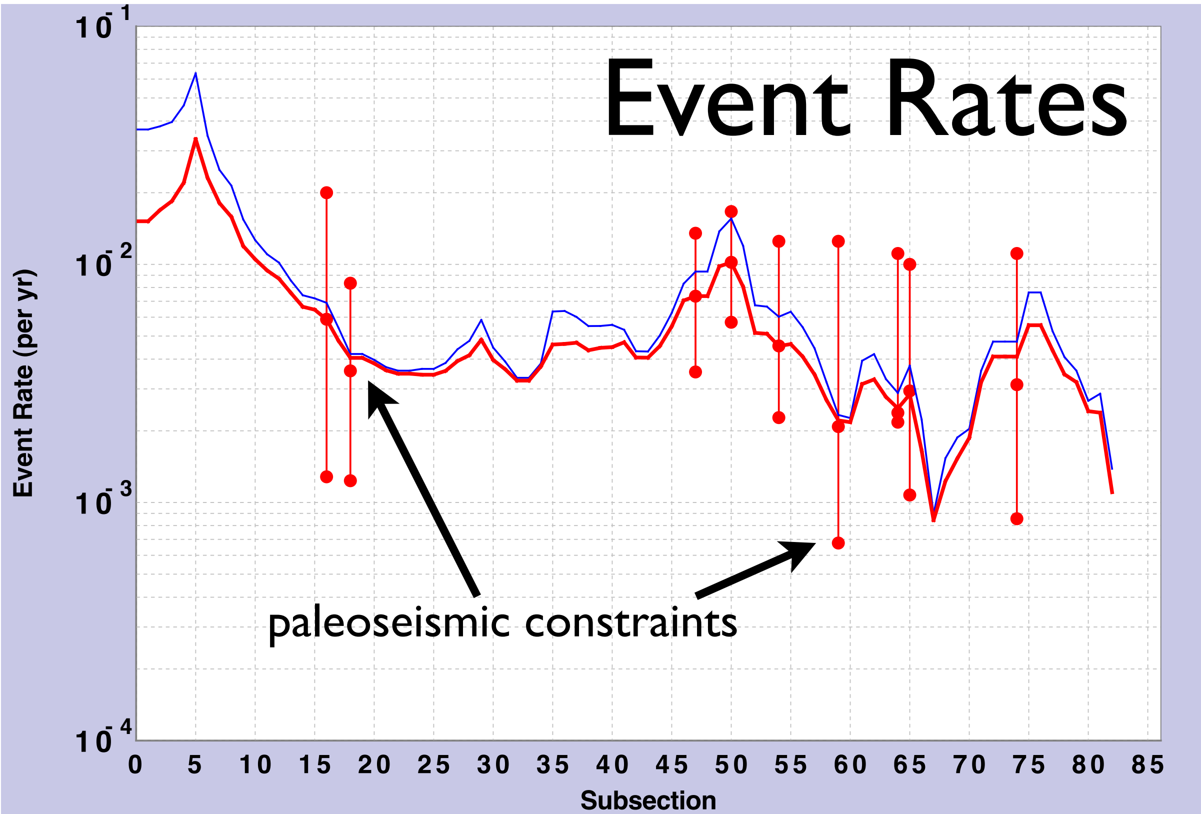


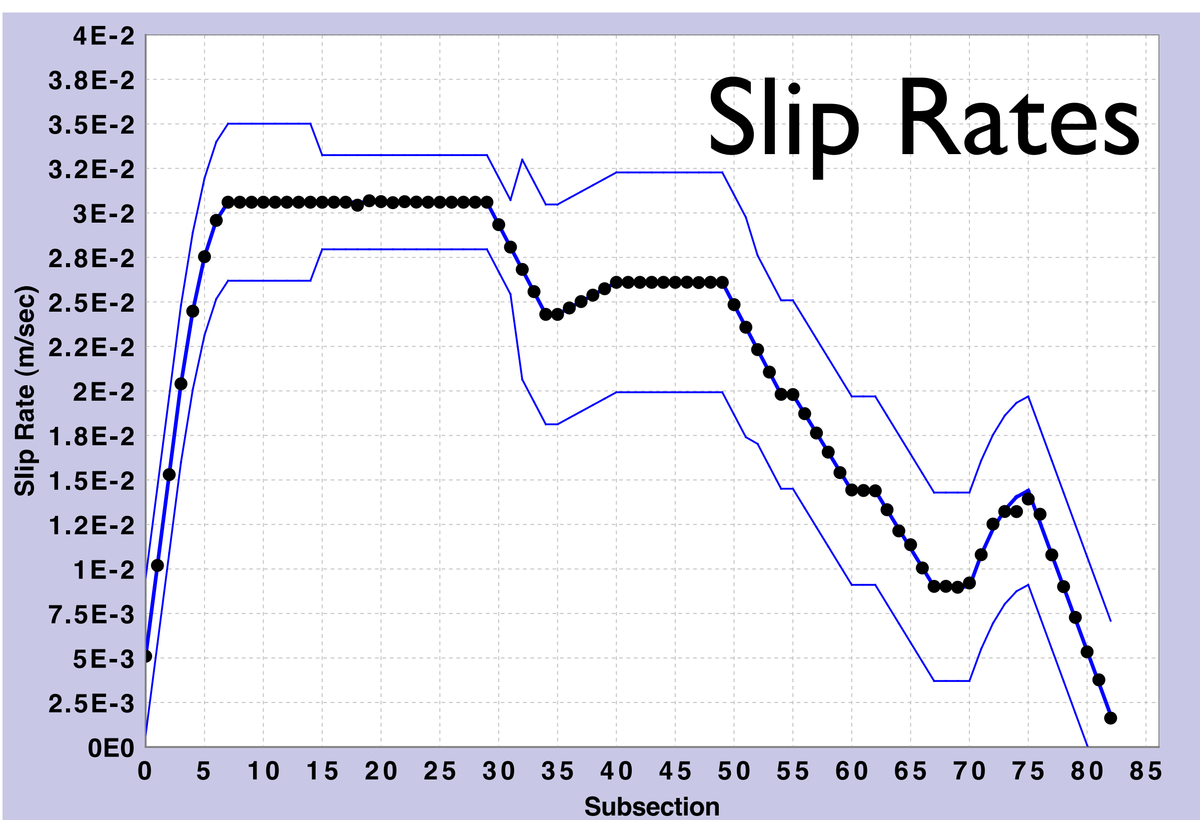
Morgan Page and Ned Field

UCERF3 Planning Meeting

Dec. 1, 2009

Generalized Inversion for Southern San Andreas Fault





Parkfield - - - - - - - - - - - - - > Coachella

- Solves for rupture rates objectively
- Avoids segmentation
- Can incorporate fault-to-fault jumps
- Can produce multiple models that fit the data
- Extendable to entire mapped fault system (UCERF3)

Ways to Solve the Inverse Problem

Ax=d, x>=0

NNLS algorithm

- Gives one solution (typically on the solution-space boundary)
- Fast for small problems, but not feasible for large problems
- Solution is (one) global minimum

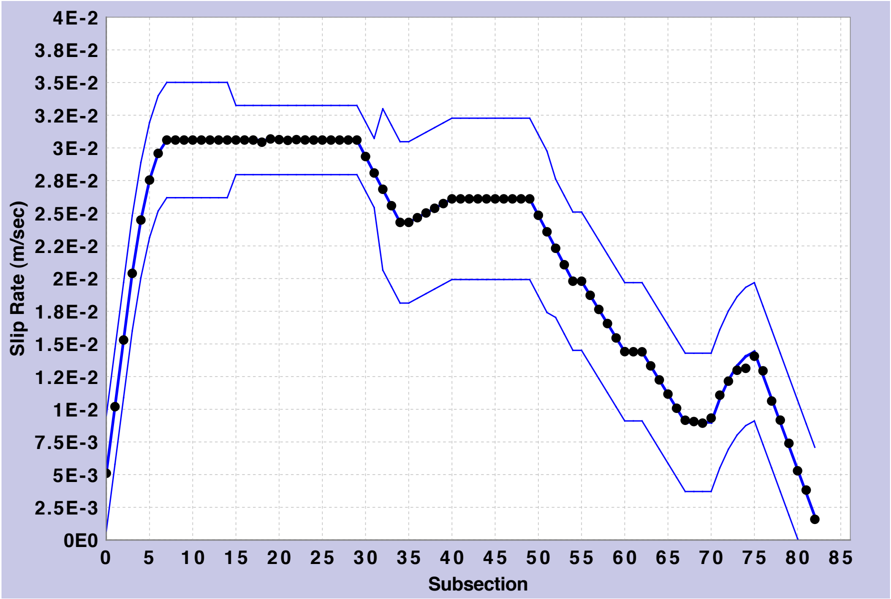
Simulated Annealing

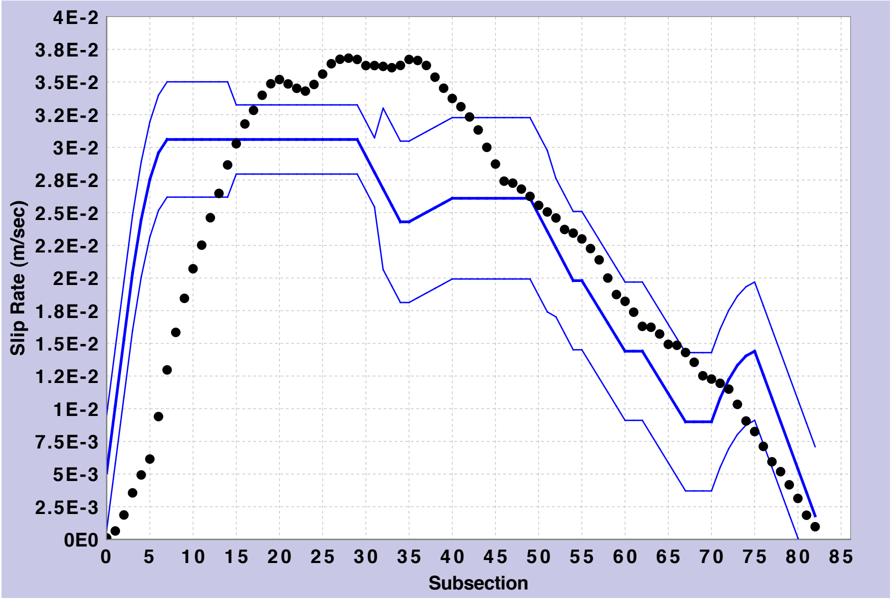
- Gives many solutions (local minima throughout solution space)
- Slower than NNLS for small problems, but scales better
- Solution converges to global minimum at t=∞

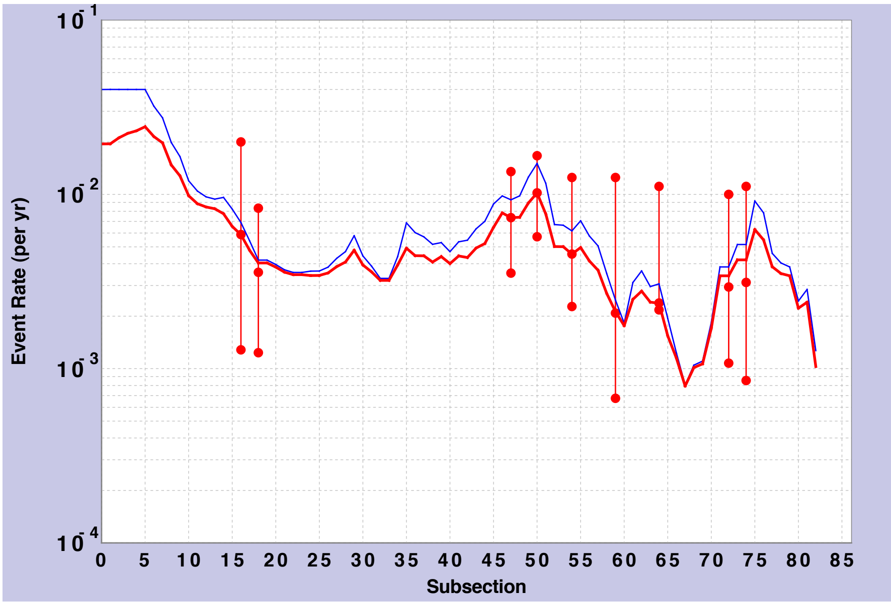
Convergence of Simulated Annealing Solutions

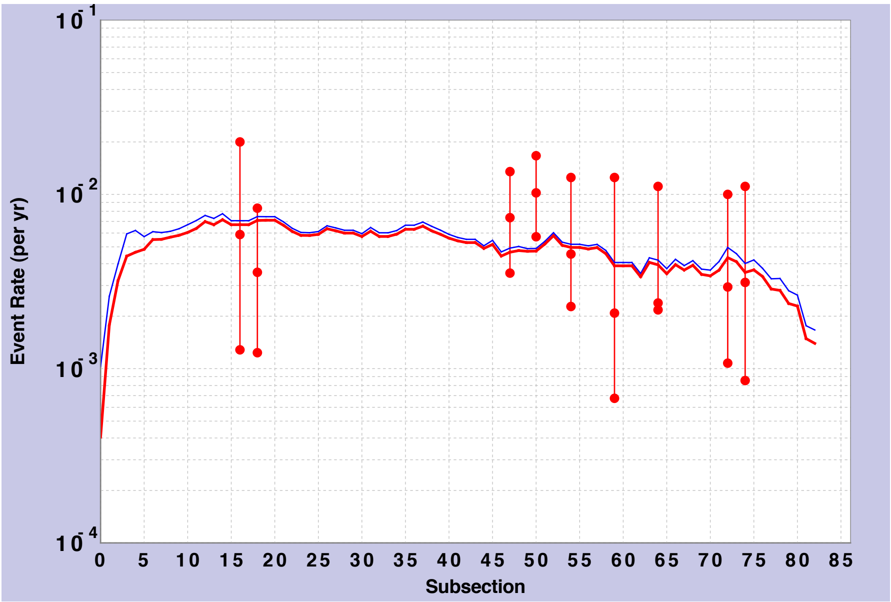
NNLS Solution
6 seconds
Data Error=0.57

SA Solution: 1,000 iterations
7 seconds
Data error=939.43



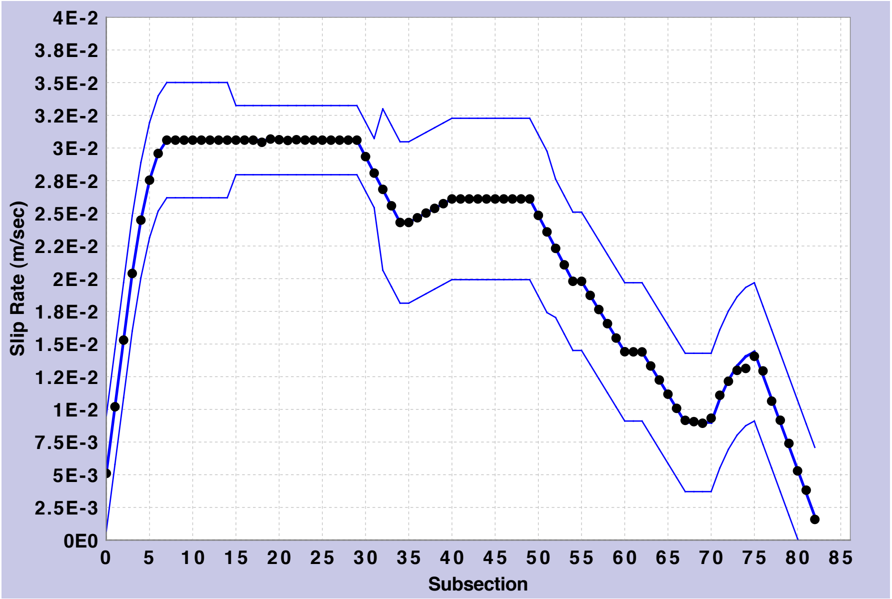


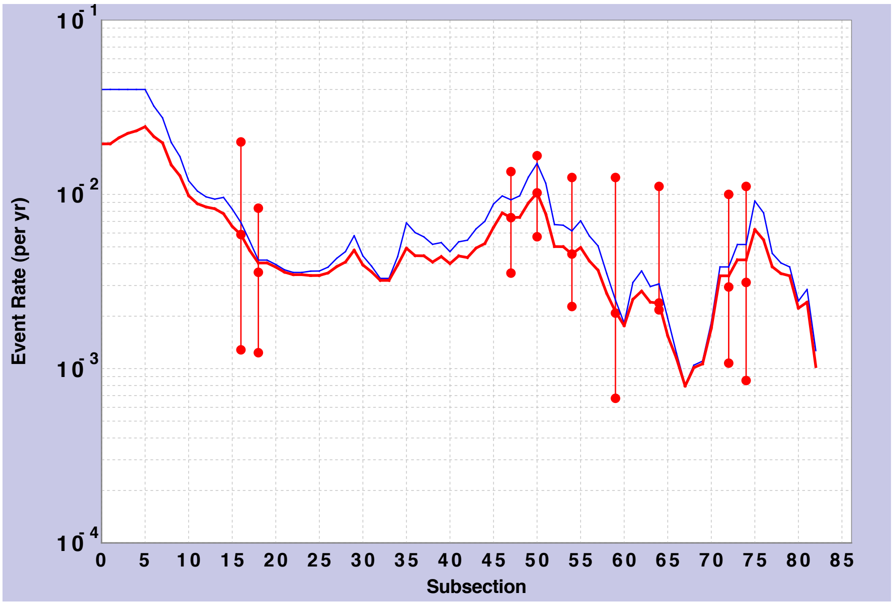




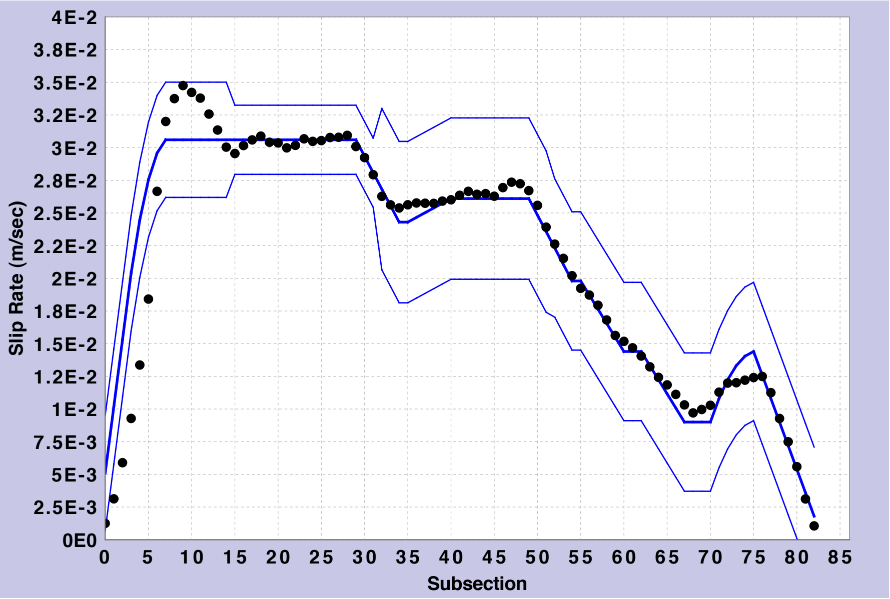
Convergence of Simulated Annealing Solutions

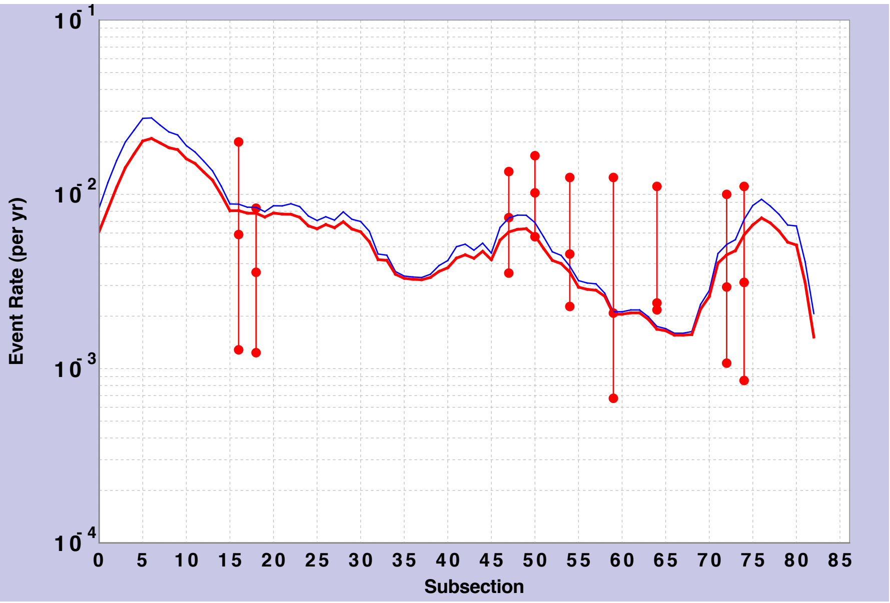
NNLS Solution
6 seconds
Data Error=0.57





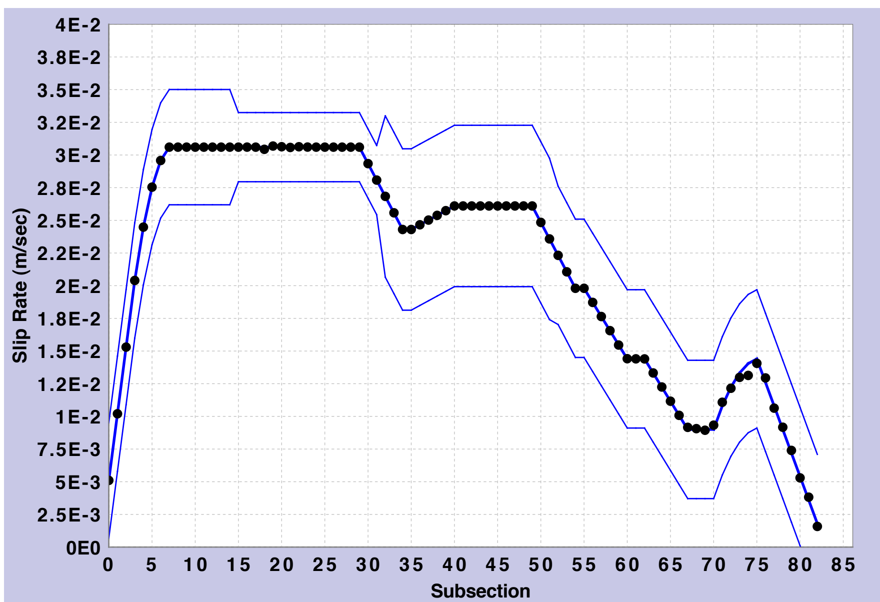
SA Solution: 10,000 iterations
14 seconds
Data error=121.79

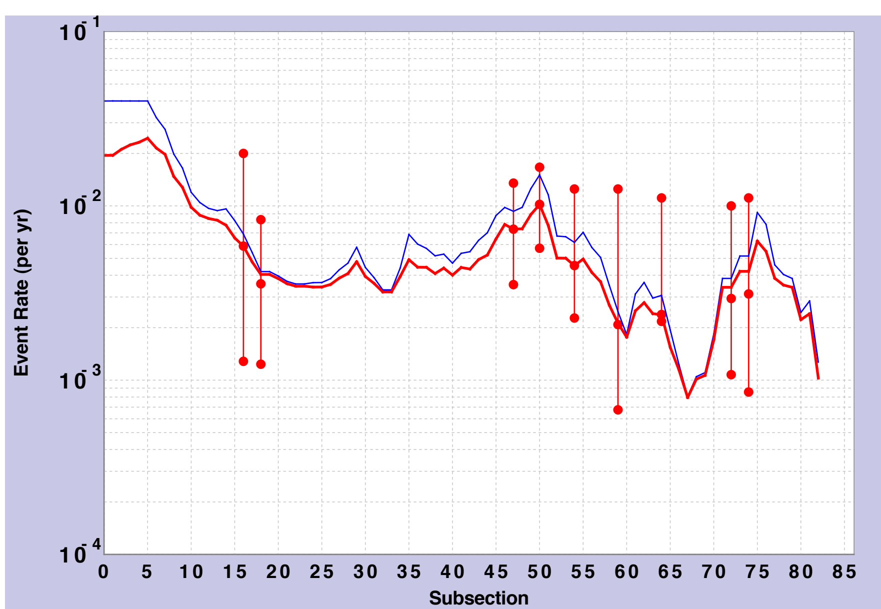




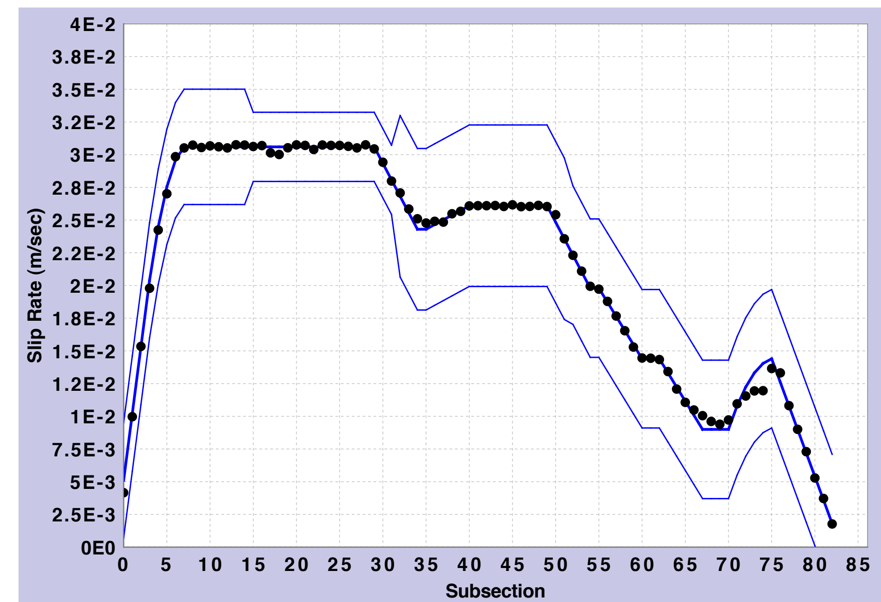
Convergence of Simulated Annealing Solutions

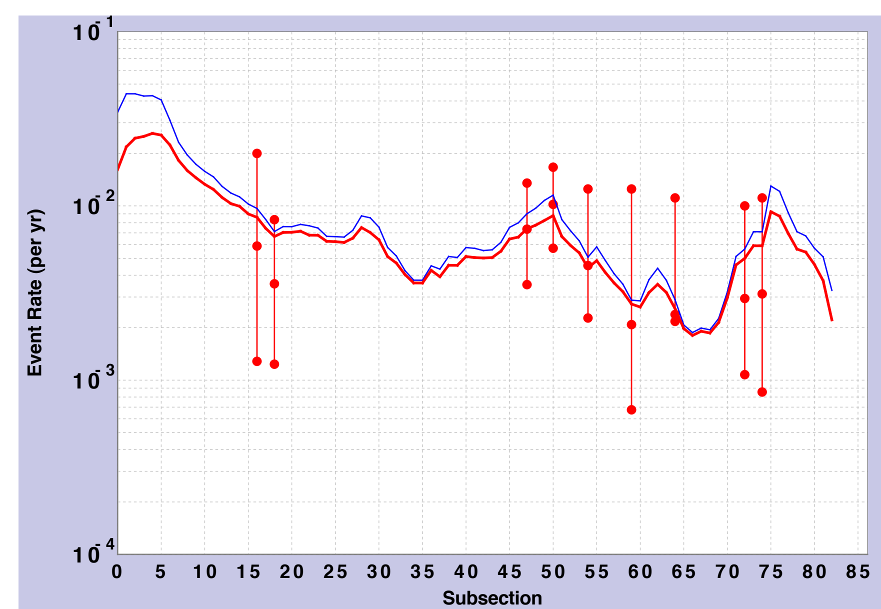
NNLS Solution
6 seconds
Data Error=0.57





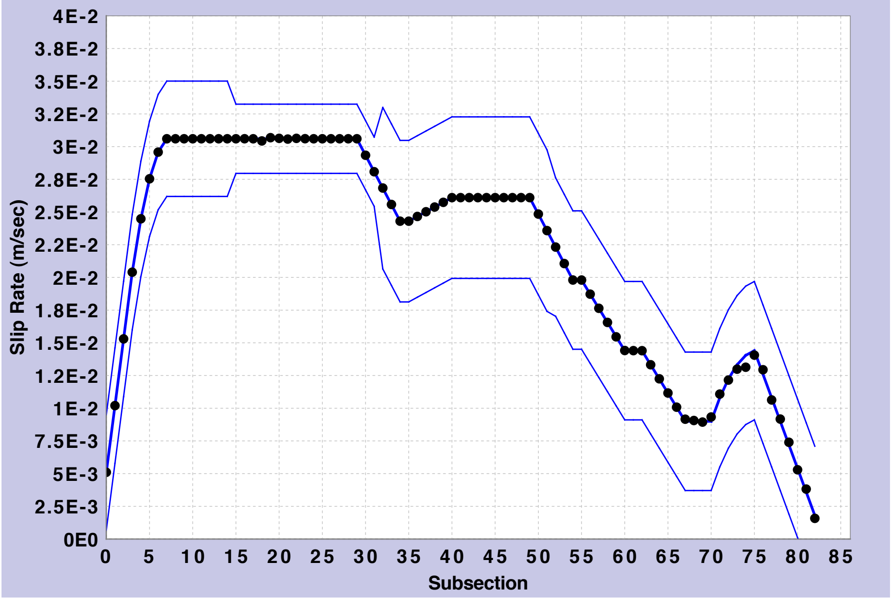
SA Solution: 100,000 iterations
94 seconds
Data error=8.00

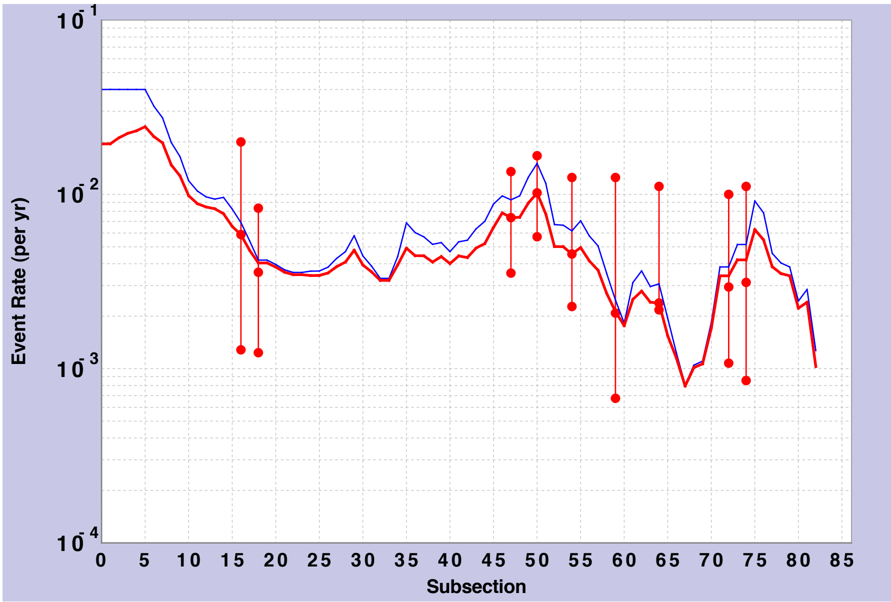




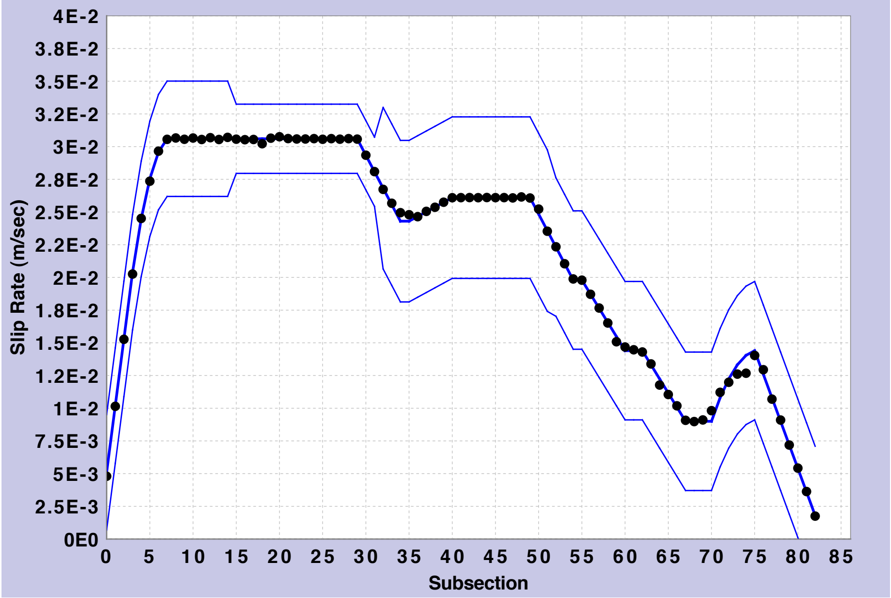
Convergence of Simulated Annealing Solutions

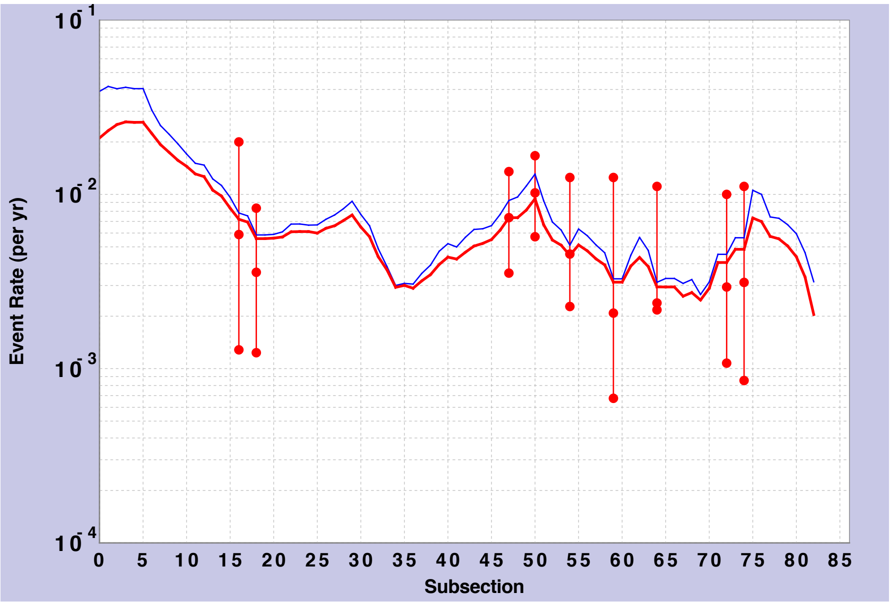
NNLS Solution
6 seconds
Data Error=0.57



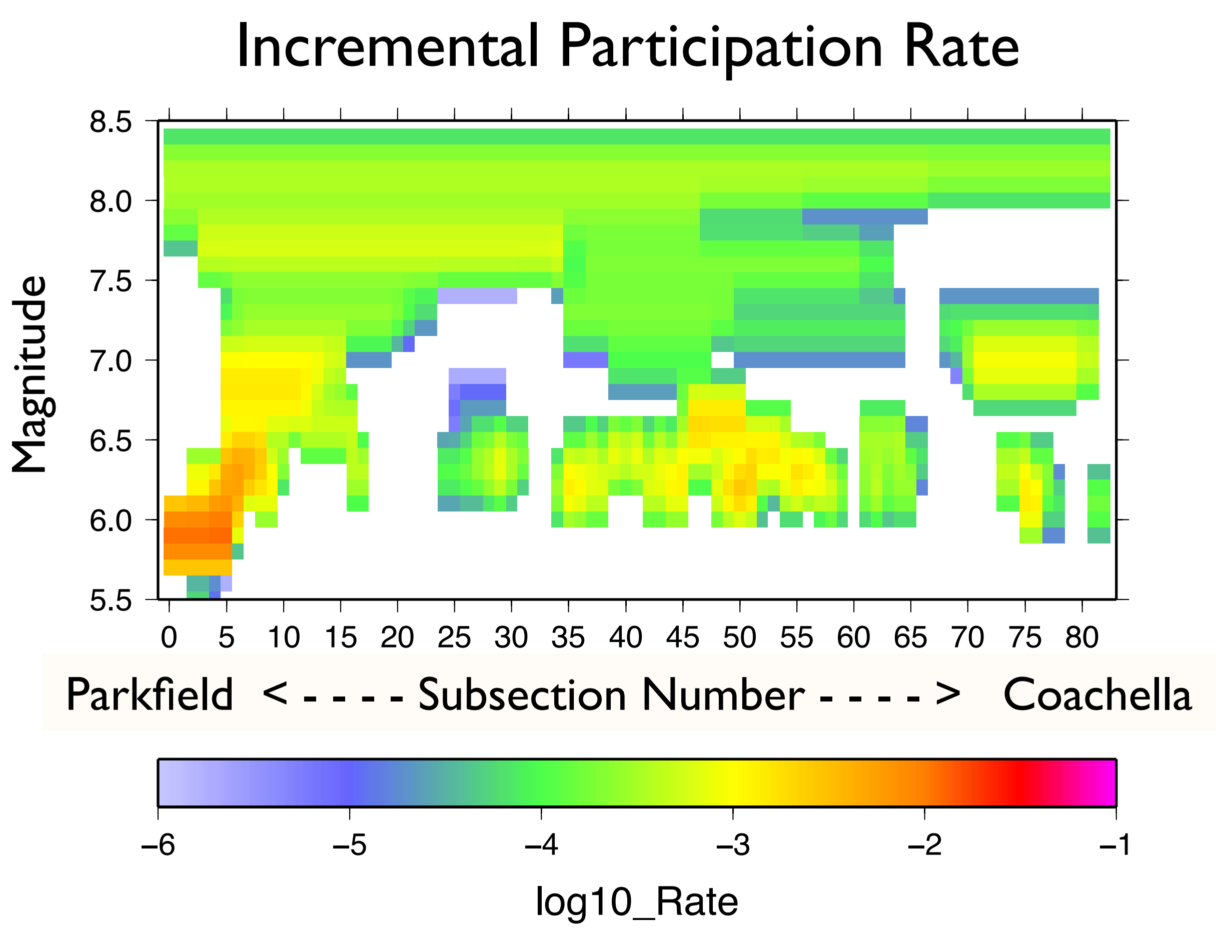


SA Solution: 1,000,000 iterations
908 seconds
Data error=2.97

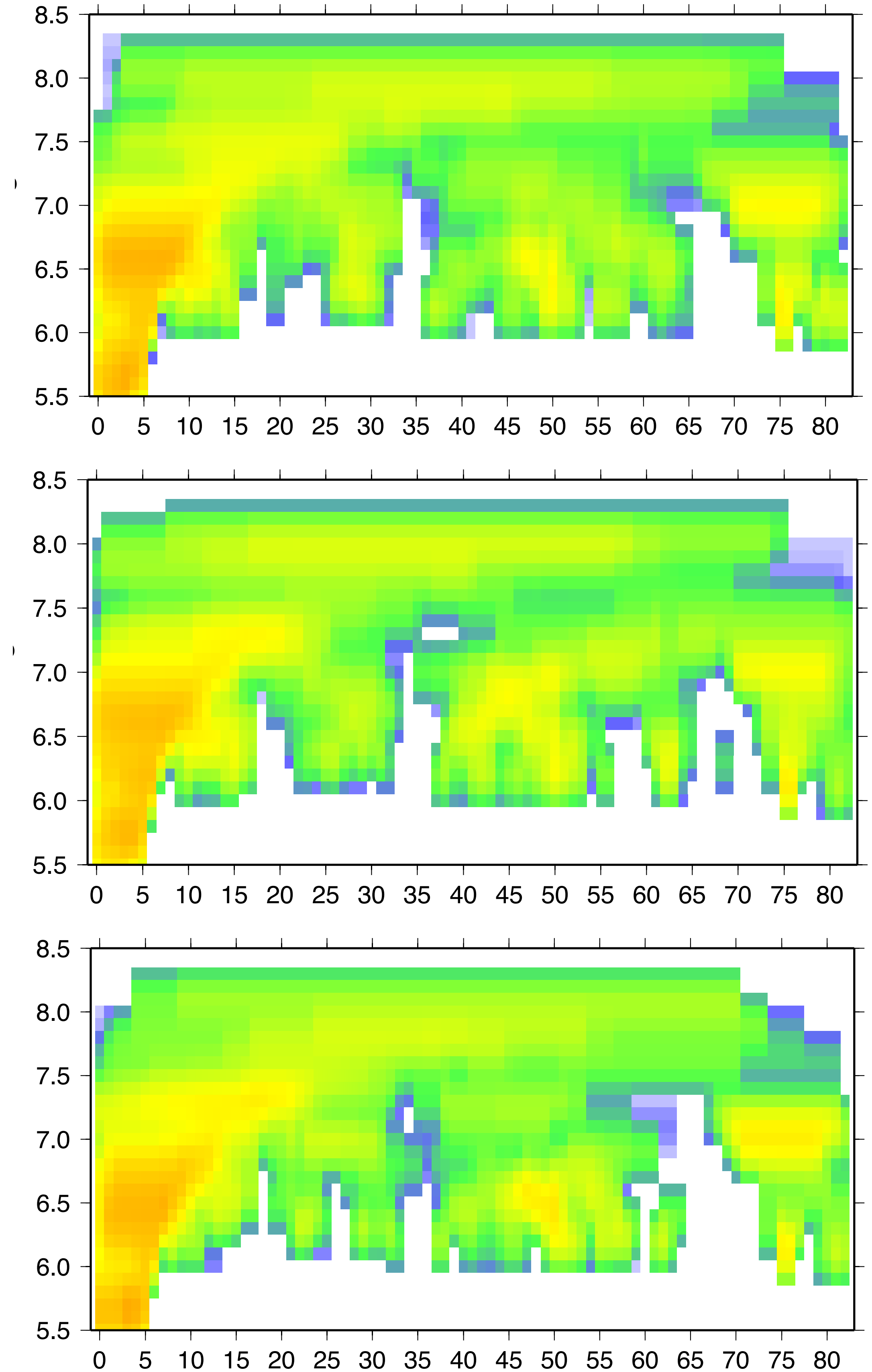




Simulated annealing solutions have fewer zero rupture rates



NNLS Solution



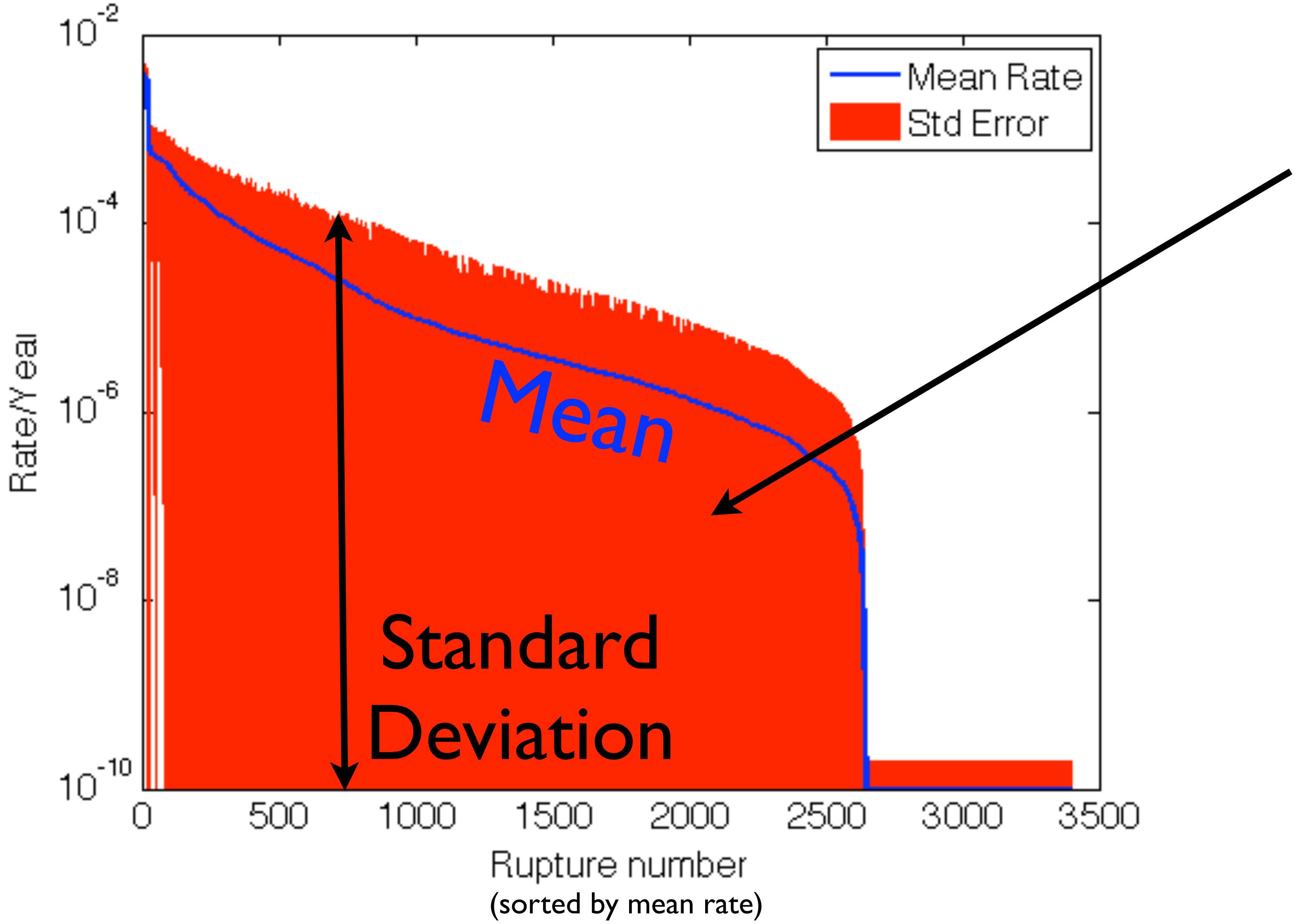
Simulated Annealing Solutions

Simulated Annealing Can Capture Both Types of Model Error

Data (Perturbation) Error	Resolution Error
how do rupture rates depend on perturbations in: *deformation model, slip model, event rates, magnitude-area relationship, fault model, etc.*	for one realization of data, range of models that fit

Simulated annealing algorithm gives multiple models

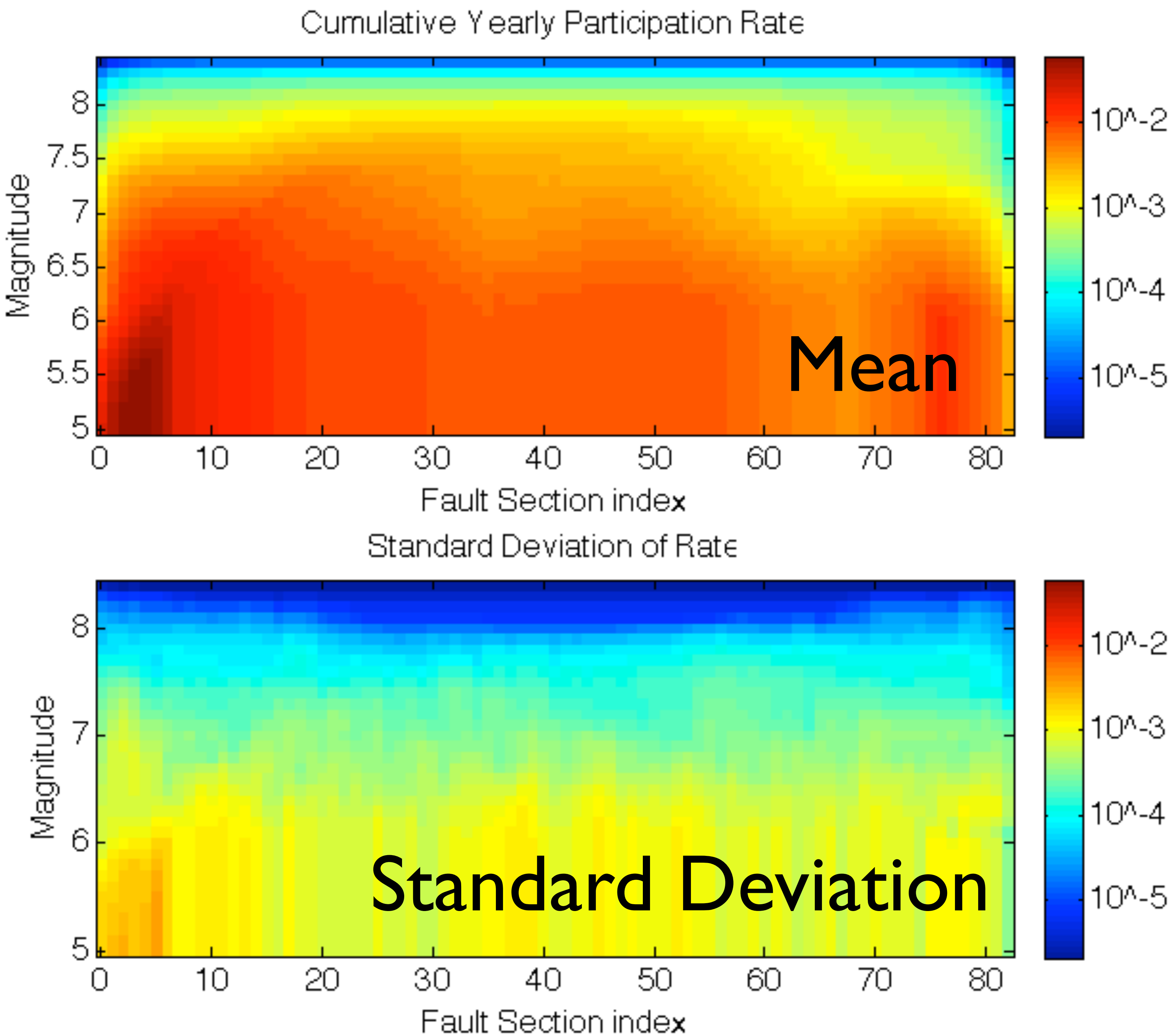
Some parameters are poorly constrained by the data...



Resolution error of individual rupture rates is very large!

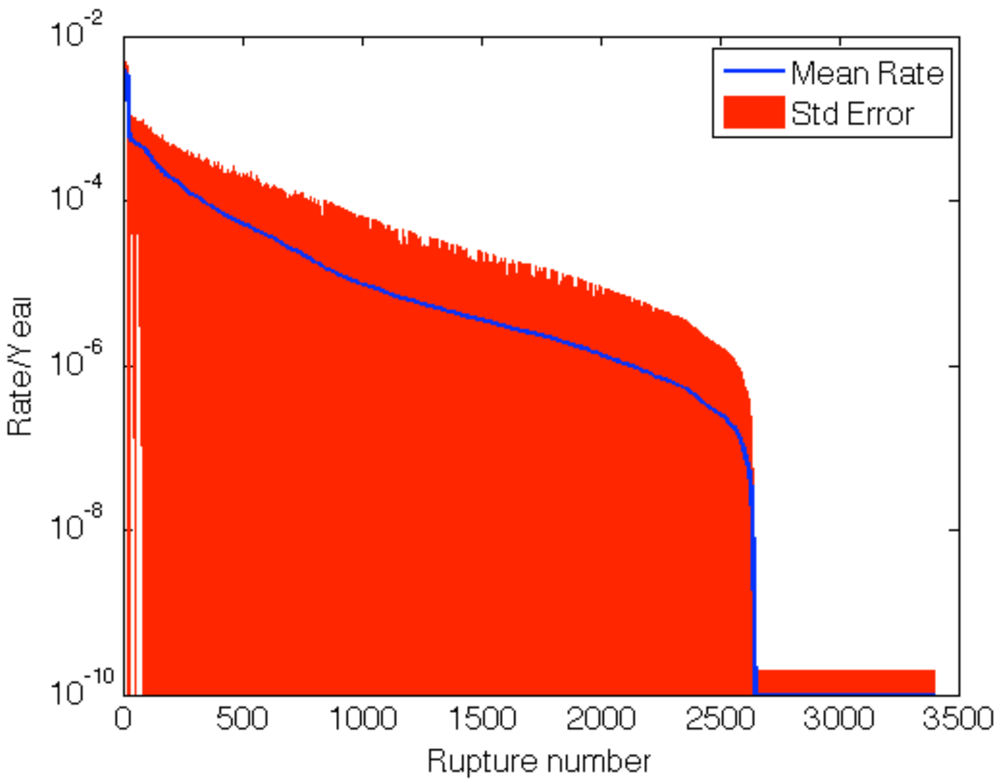
Simulated annealing algorithm gives multiple models

We can determine which features change little between the models.

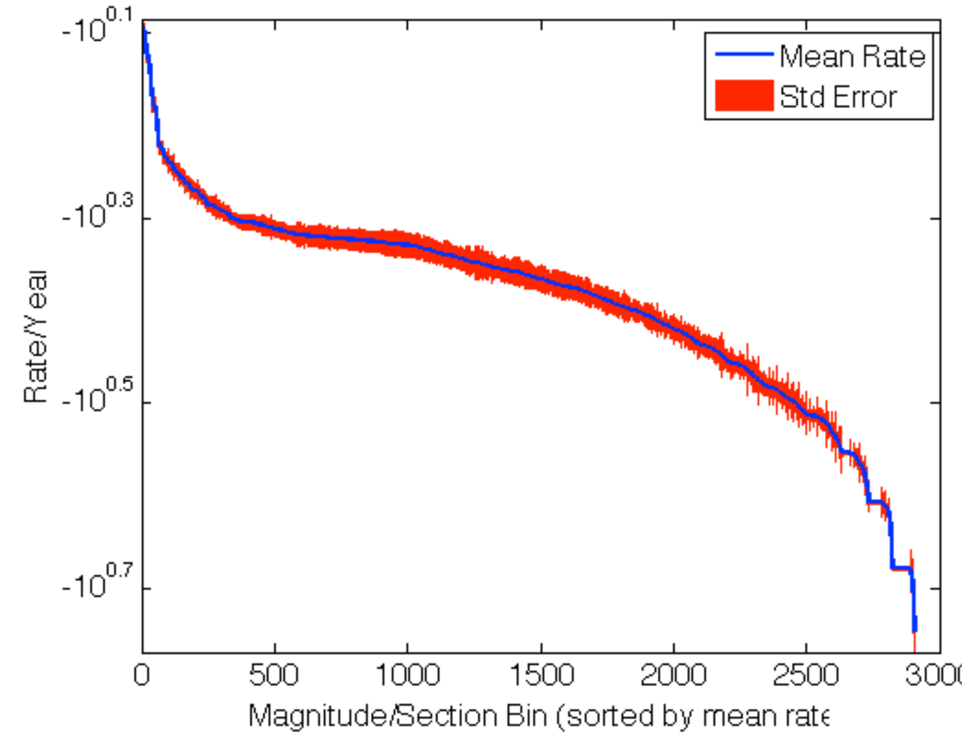


The rate at which an individual fault section participates in an event of a given magnitude is constrained much more than individual rupture rates

Simulated annealing algorithm gives multiple models



Poorly constrained!

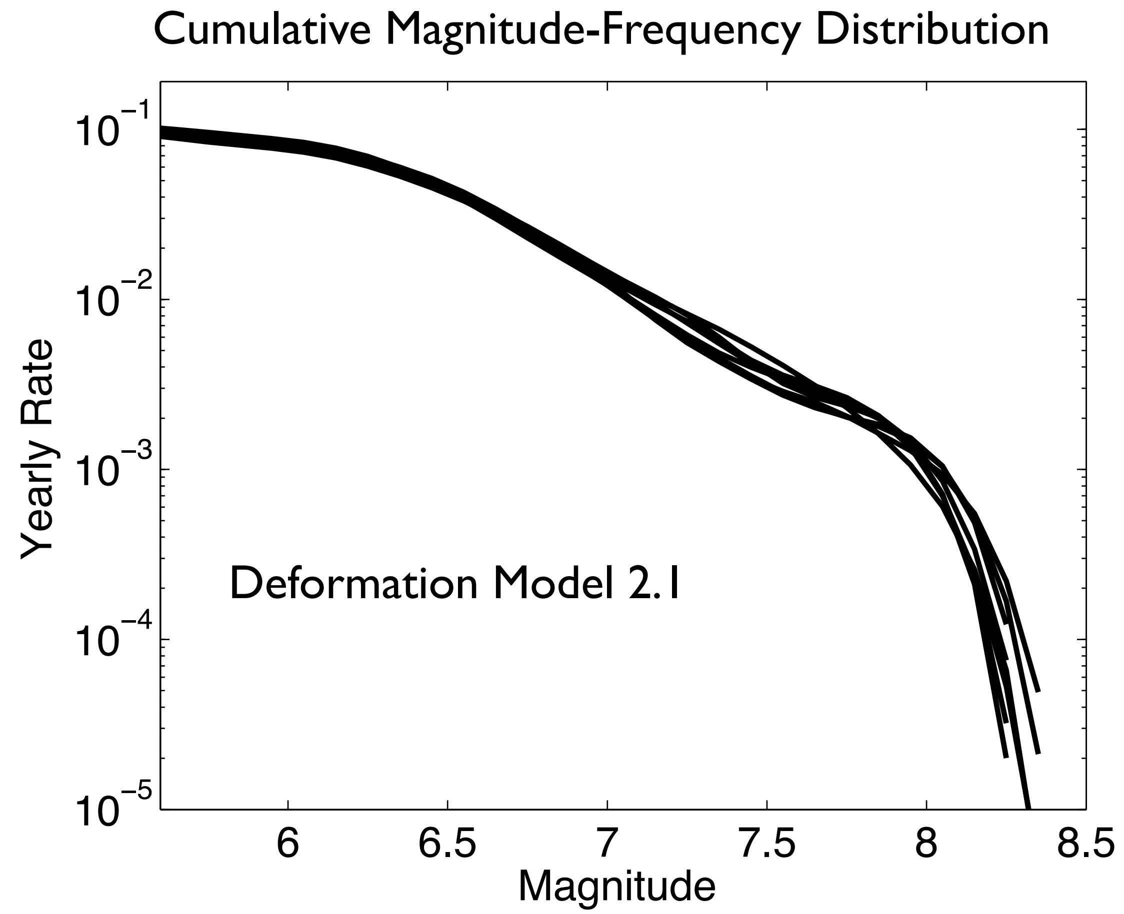


Well constrained!

Any individual rupture rate could be zero (there is enough wiggle room in the other parameters) ...
only *linear combinations* of rupture rates are well-constrained!

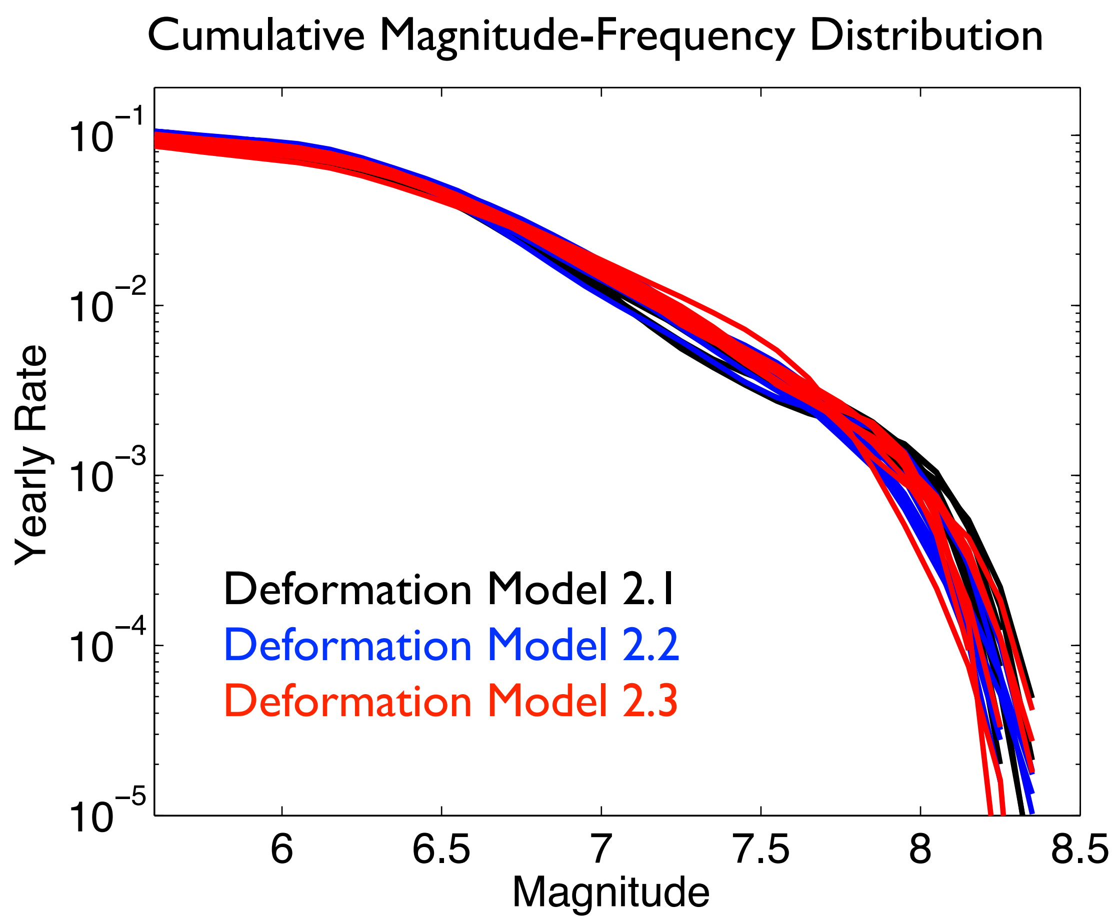
How the magnitude-frequency distribution change with...

Deformation Model



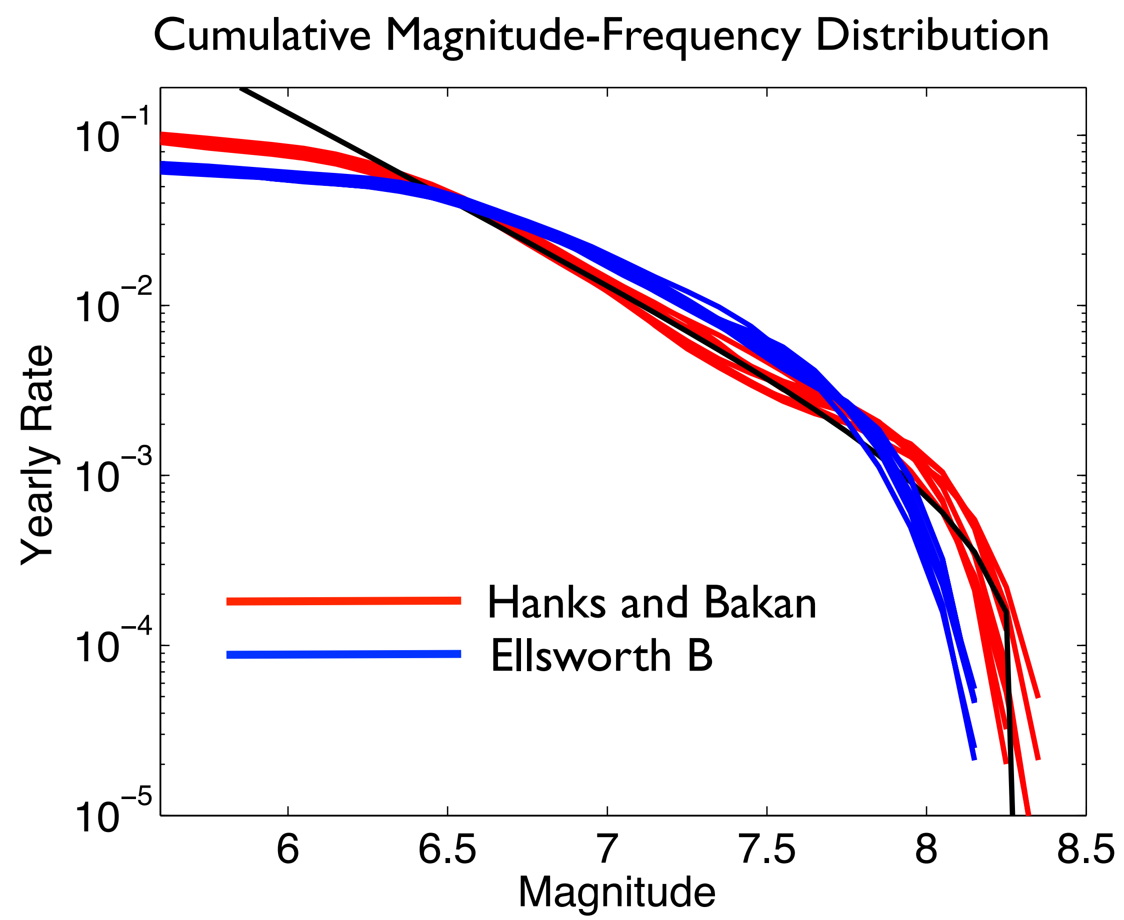
How the magnitude-frequency distribution change with...

Deformation Model



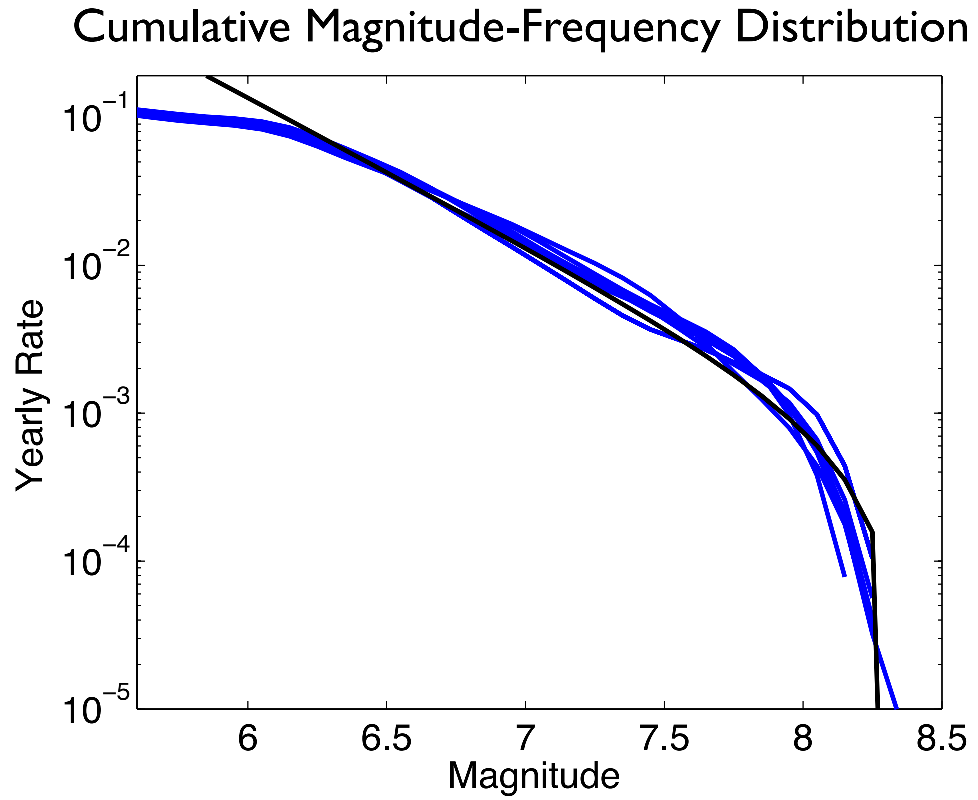
How the magnitude-frequency distribution change with...

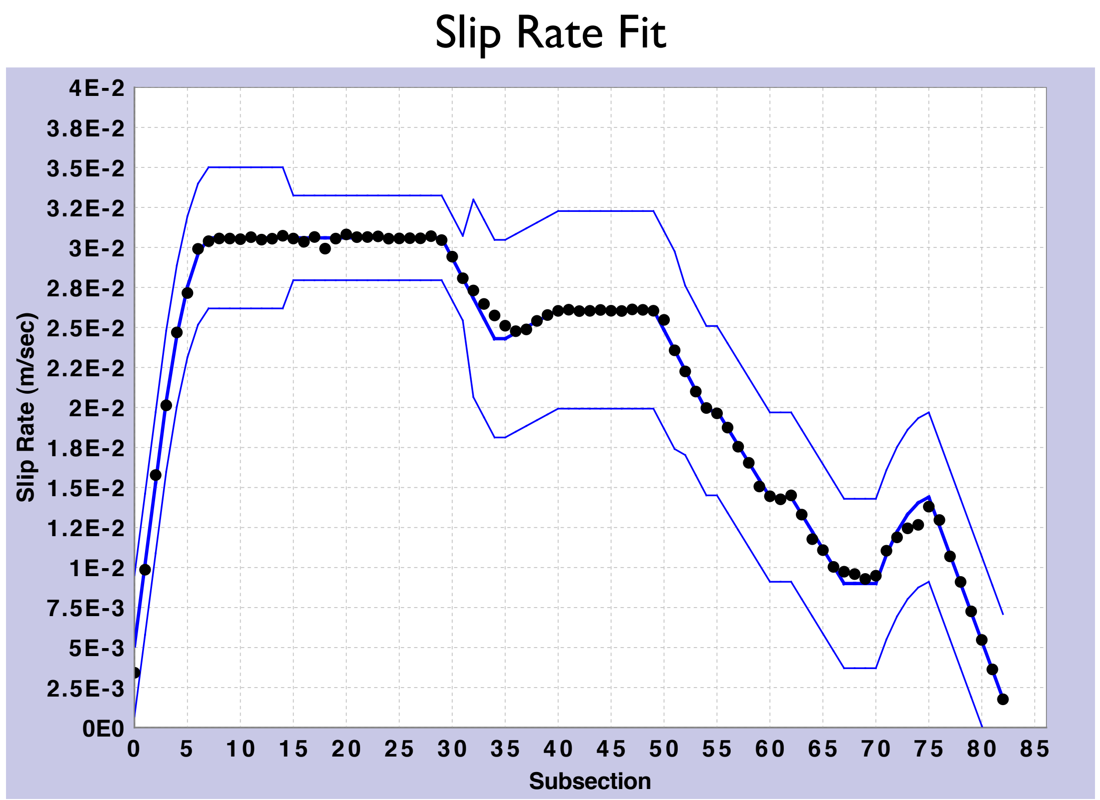
Magnitude-Area Relationship



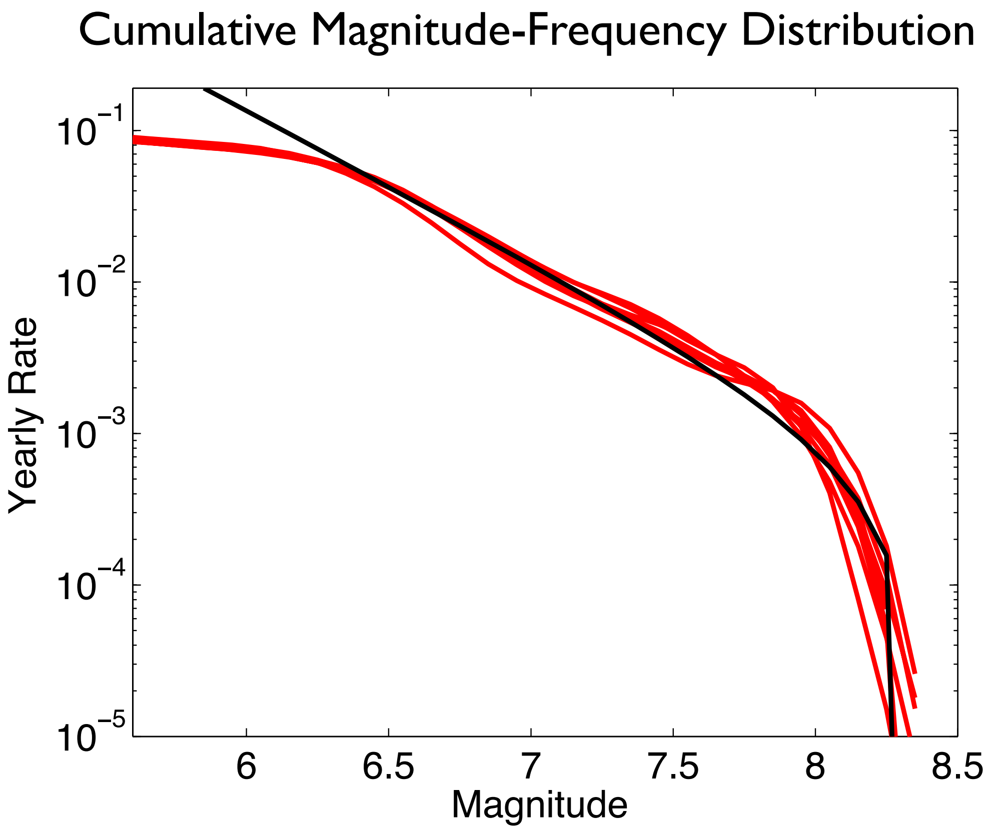
The magnitude-frequency distribution of the solution is fairly robust.

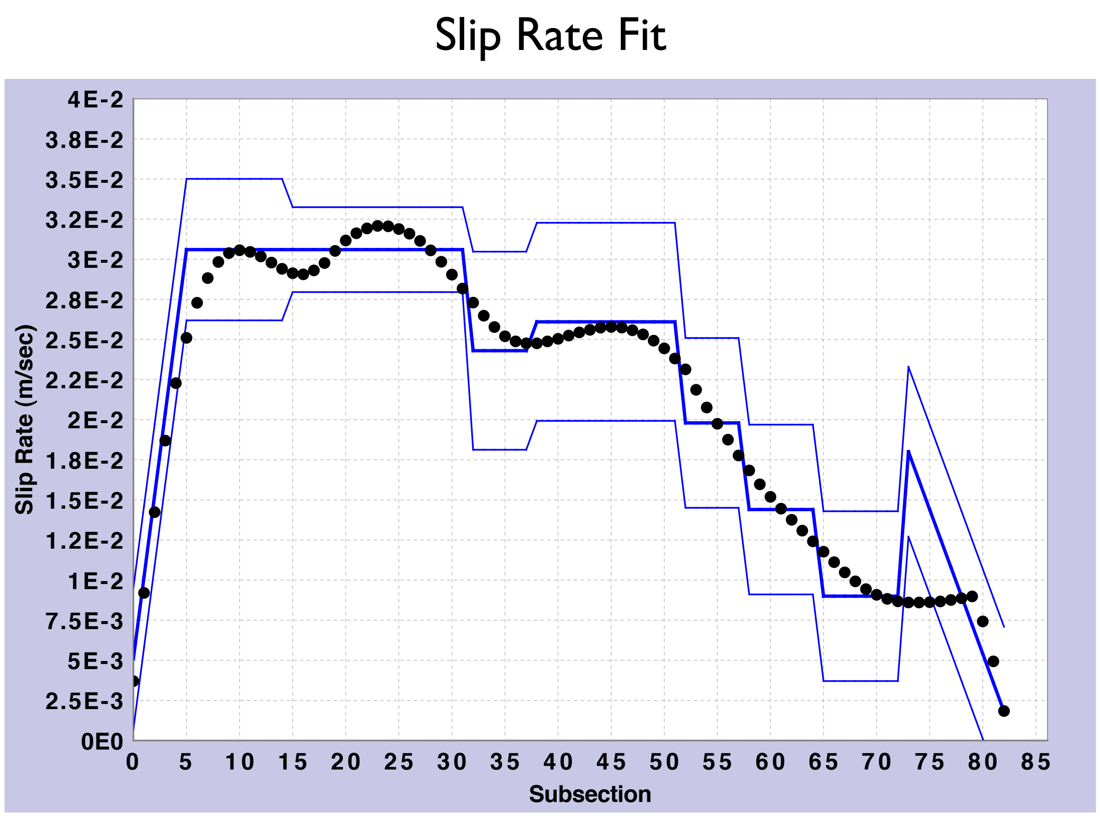
Different Ways of Constraining Slip Rate





Smooth slip rate data; Constrain at every point

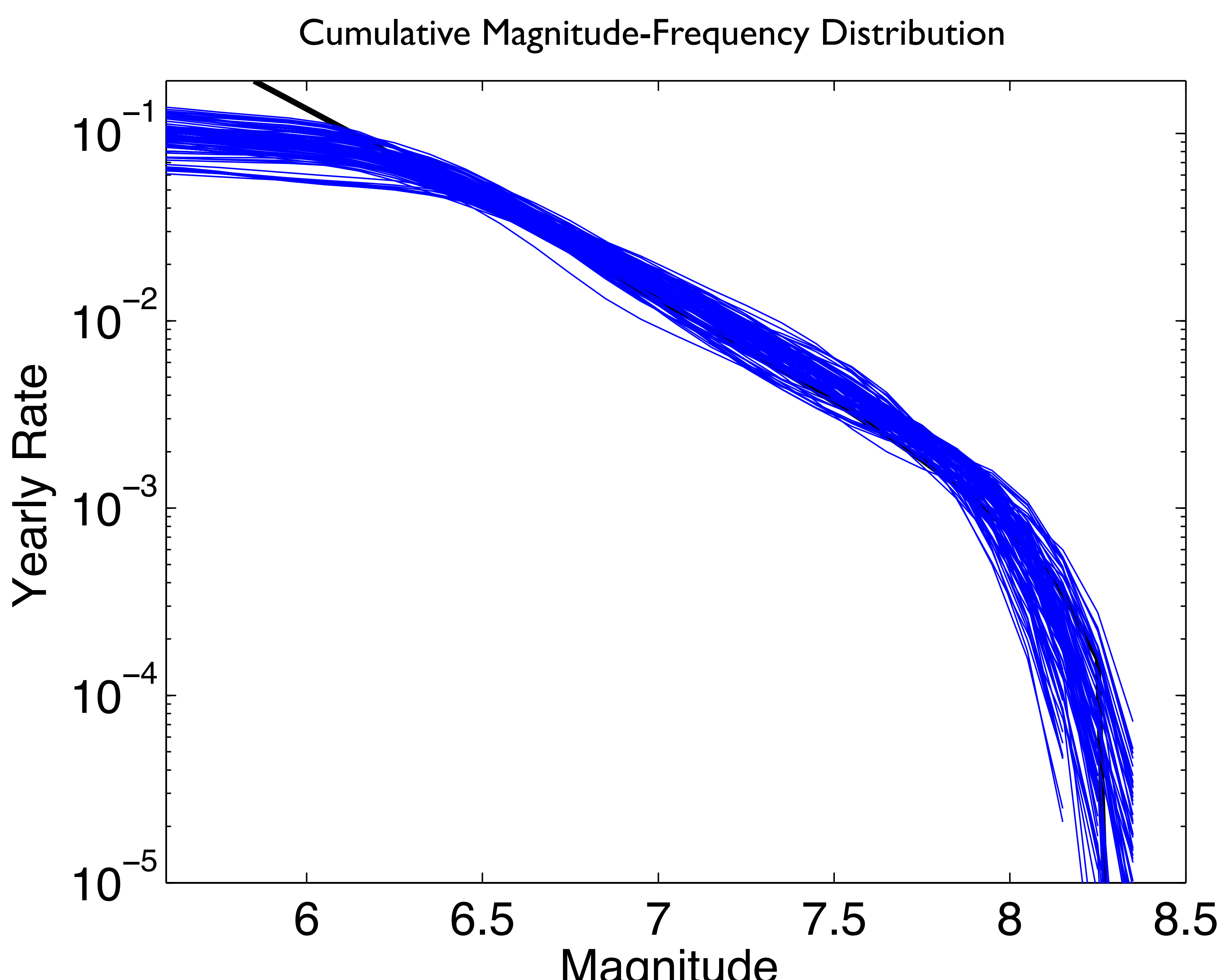


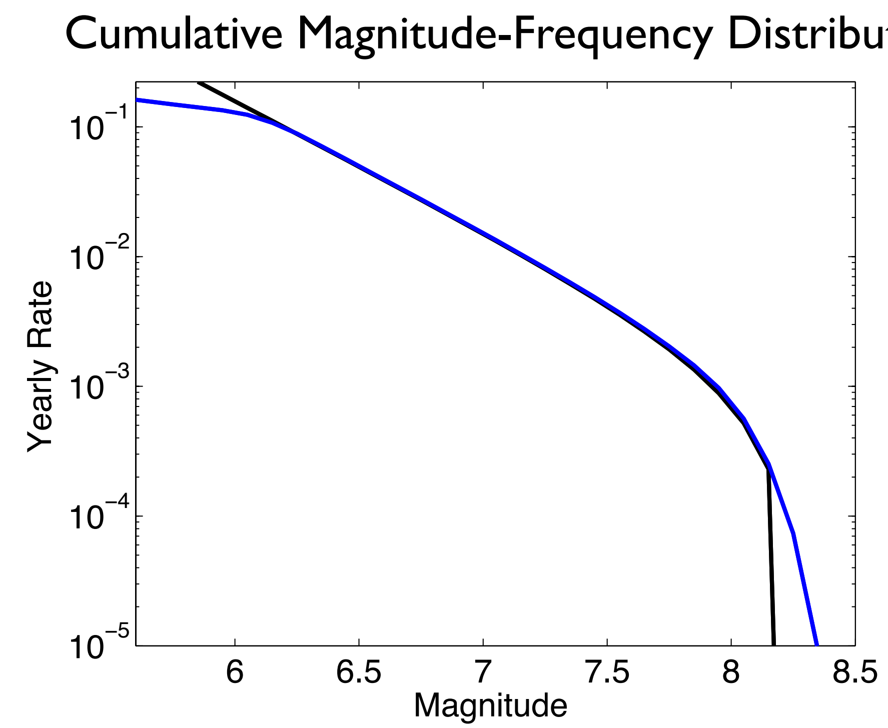


Smooth model's slip rate; Constrain only at segment centers

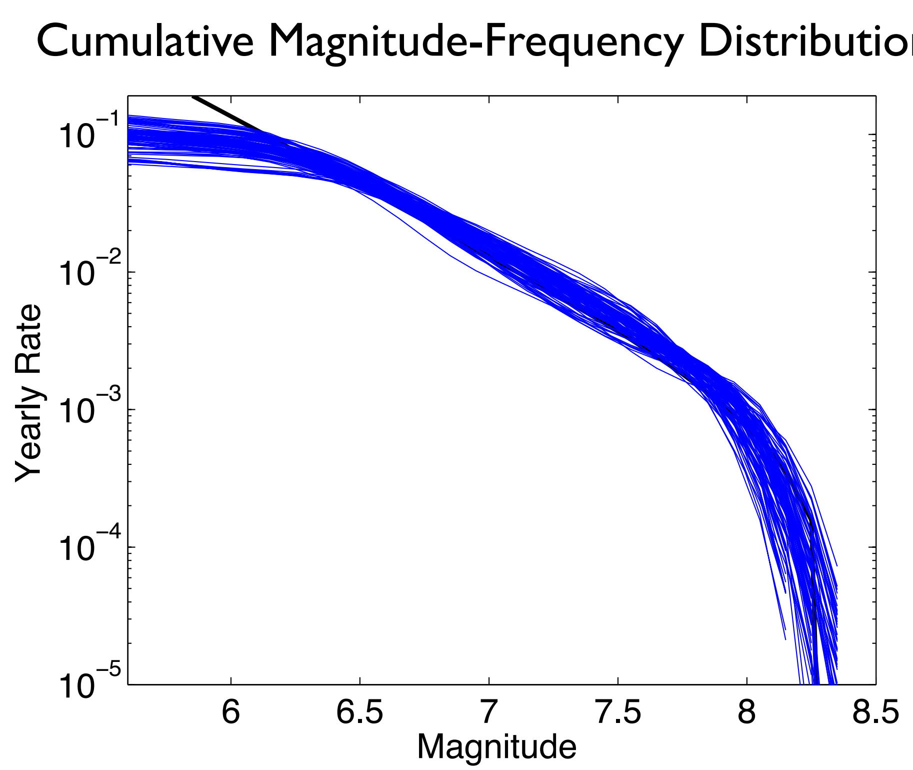
All Magnitude-Frequency Distributions from Parameter Exploration

Includes variation in: Deformation model, magnitude-area relationship, amount of slip-rate smoothing, type of slip-rate constraint, slip model, slip-rate transition at fault ends, aseismicity transition at fault ends, moment rate reduction





Solution can be constrained to be G-R (or any magnitude distribution)



Or the data can "choose" (no constraint)

The inversion approach can be used to incorporate physical constraints, and reduce model "tinkering"