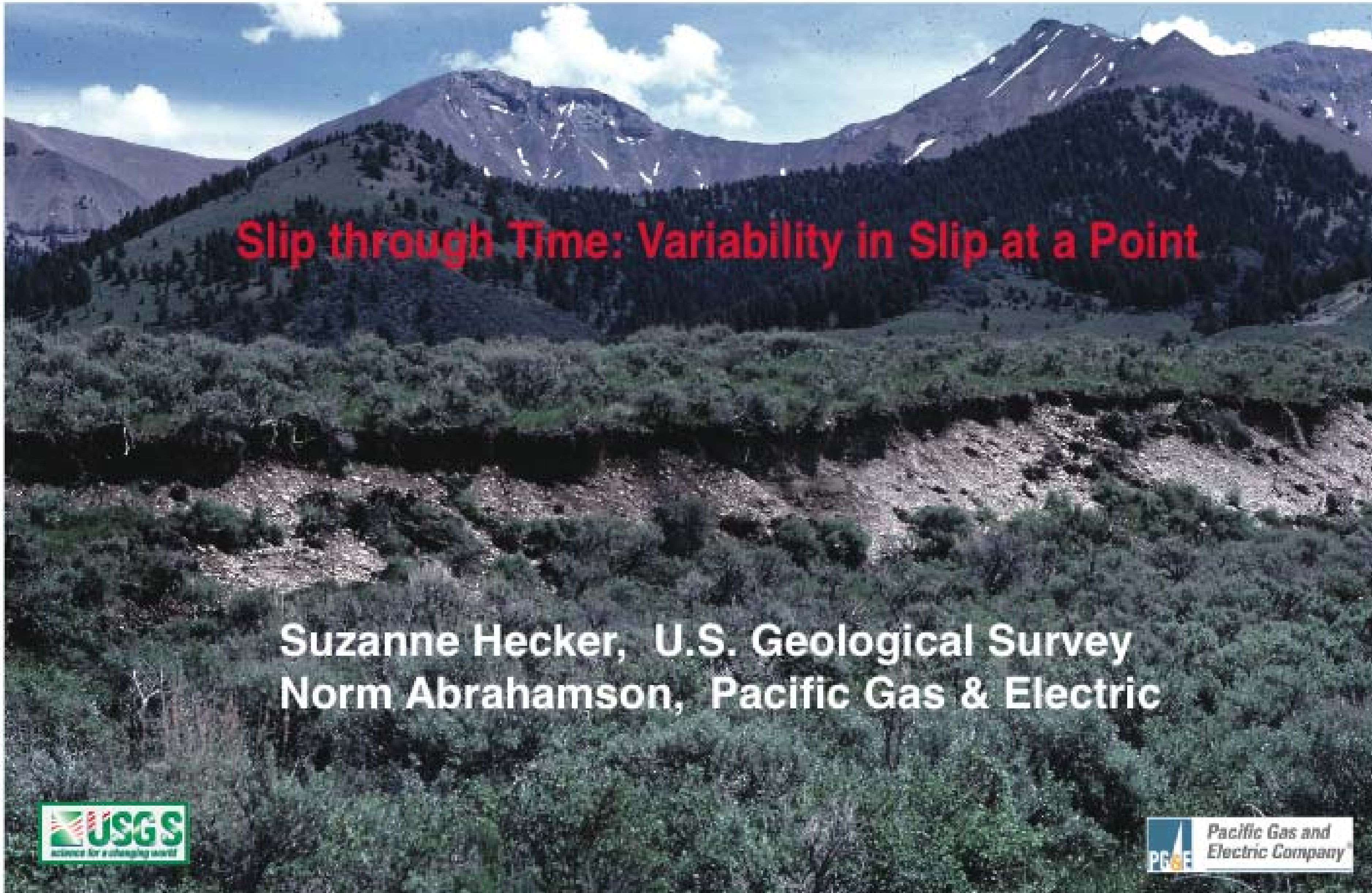
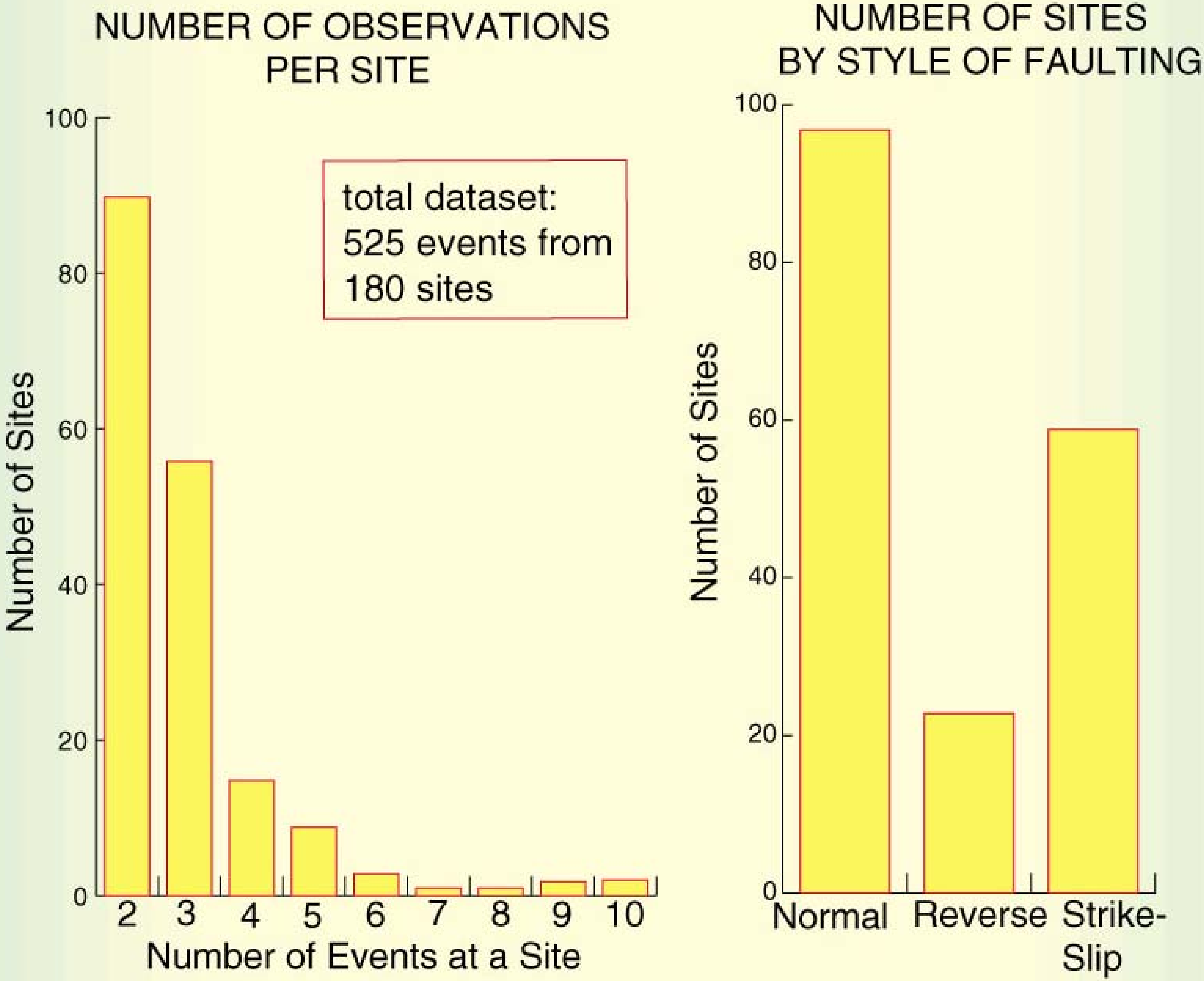

Slip through Time: Variability in Slip at a Point
Suzanne Hecker, U.S. Geological Survey
Norm Abrahamson, Pacific Gas & Electric
Pacific Gas and Electric Company

CHARACTERISTICS OF GEOLOGIC DATA SET



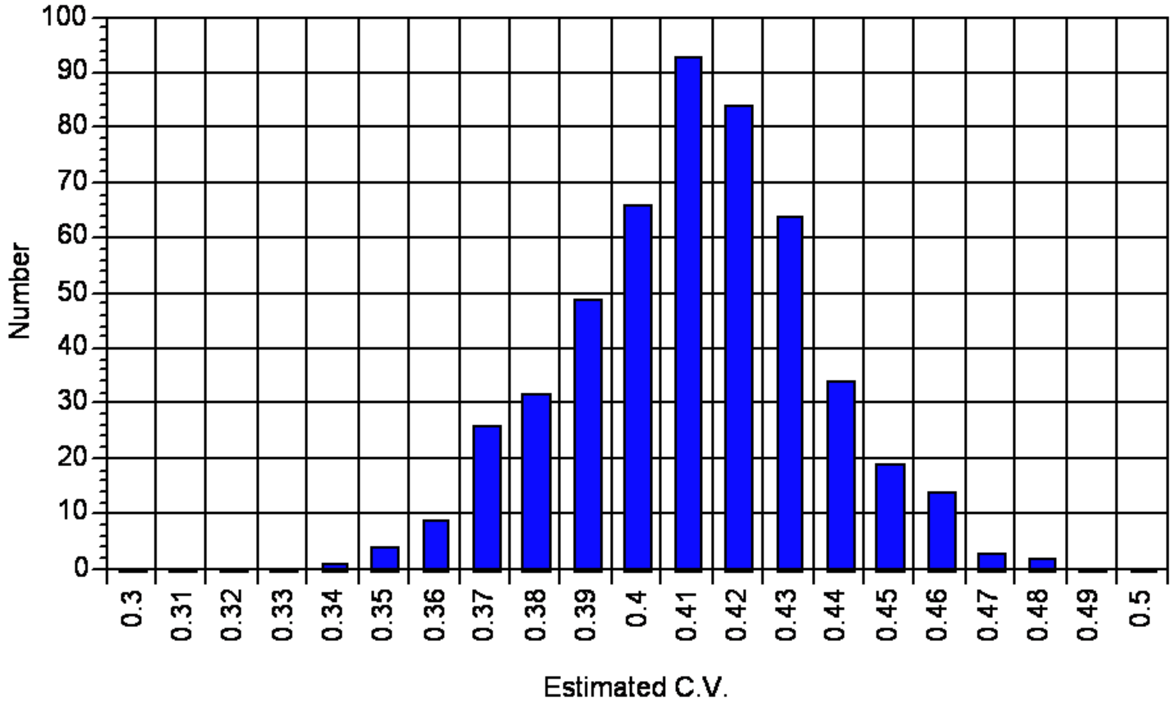
Coefficient of Variation (C.V.)

$$C.V. = \frac{\sigma_i}{\overline{D}_i} = \alpha$$

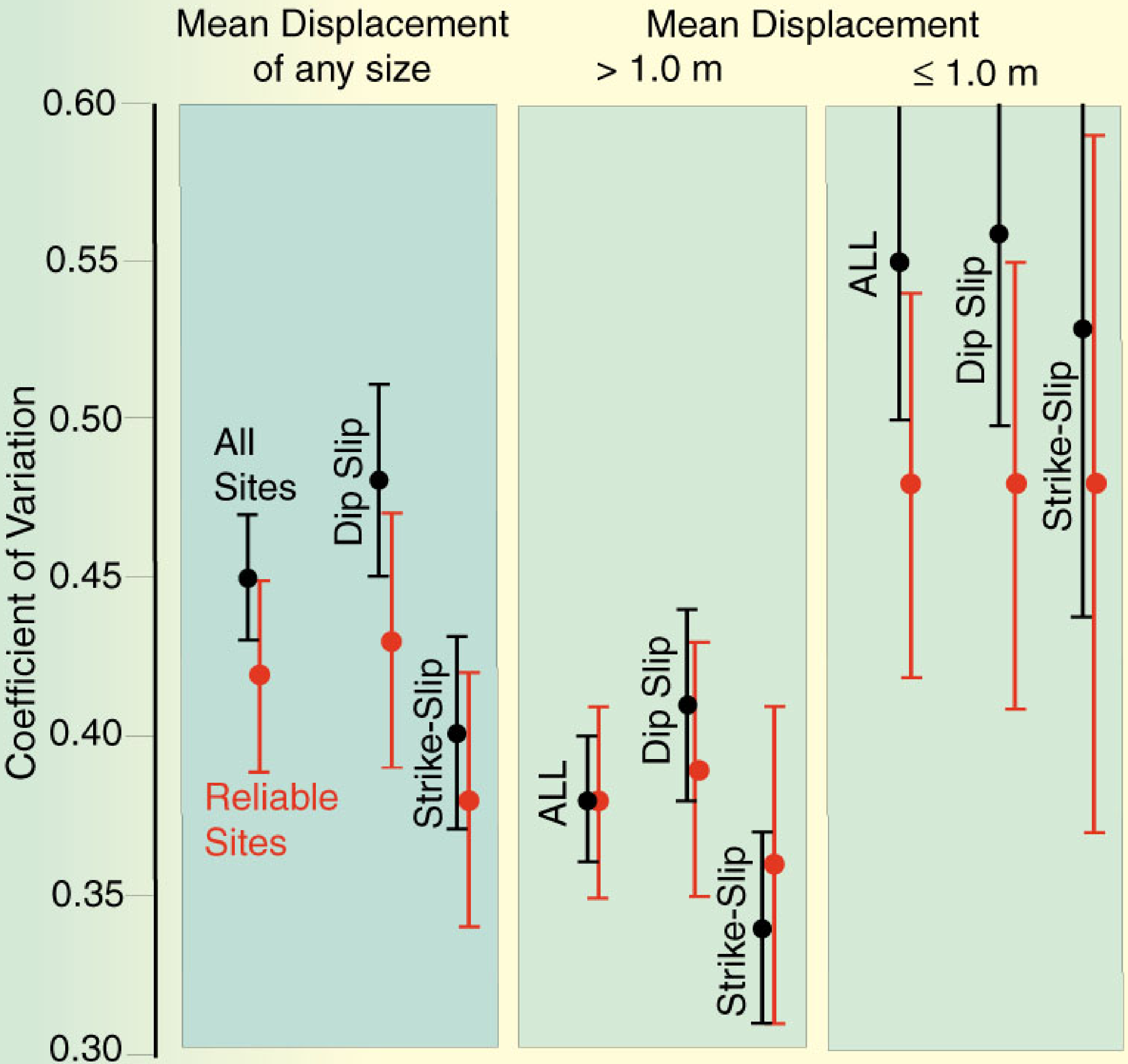
$$C.V. = \sqrt{\frac{\sum_{i=1}^{N_{site}} \sum_{j=1}^{N_i} \left(\frac{D_{ij} - \overline{D}_i}{\overline{D}_i} \right)^2}{(N_{displ} - N_{site})}}$$

Effect of Small Number of Events per Site

- Use Monte Carlo
  - Population C.V.=0.4
  - Same sampling as in data set
- Result:
  - Average C.V.=0.41 (small bias toward larger CV)



COMPUTED **COEFFICIENT OF VARIATION** FOR SLIP AT A POINT

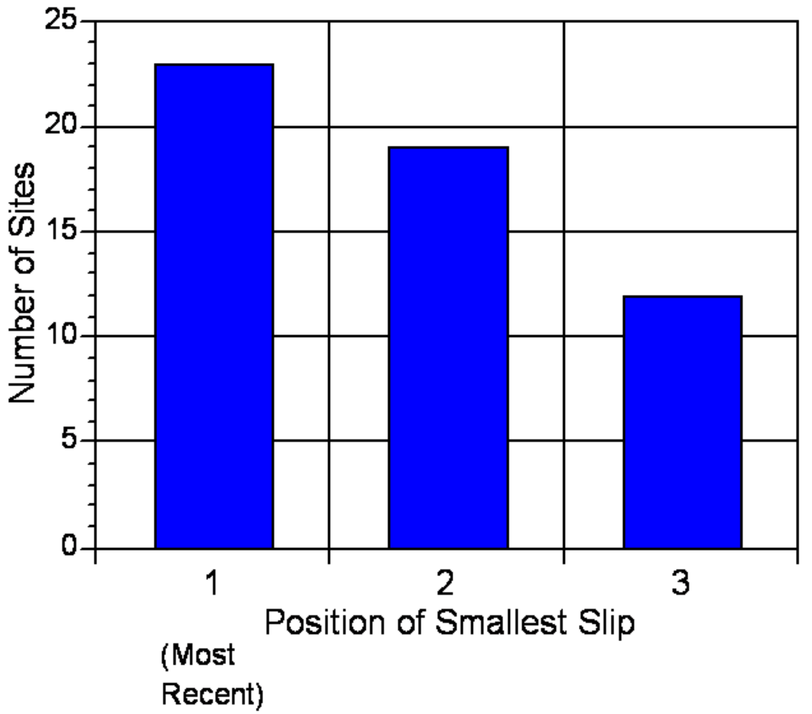


$$C.V. = \frac{\sigma_i}{\overline{D}_i} = \alpha$$

$$C.V. = \sqrt{\frac{\sum_{i=1}^{N_{site}} \sum_{j=1}^{N_i} \left(\frac{D_{ij} - \overline{D}_i}{\overline{D}_i} \right)^2}{(N_{displ} - N_{site})}}$$

$$S.E.[C.V.] = \sqrt{\frac{2(N_{displ} - N_{site})}{N_{displ}^2}} \bullet C.V.$$

Event Position of Smallest Slip



- Smallest slip is more often the most recent event
- Accommodate effect by varying the probability of detection by event position
- Calibrate using observed frequencies

Threshold of Event Detection

Model based on General Field Conditions

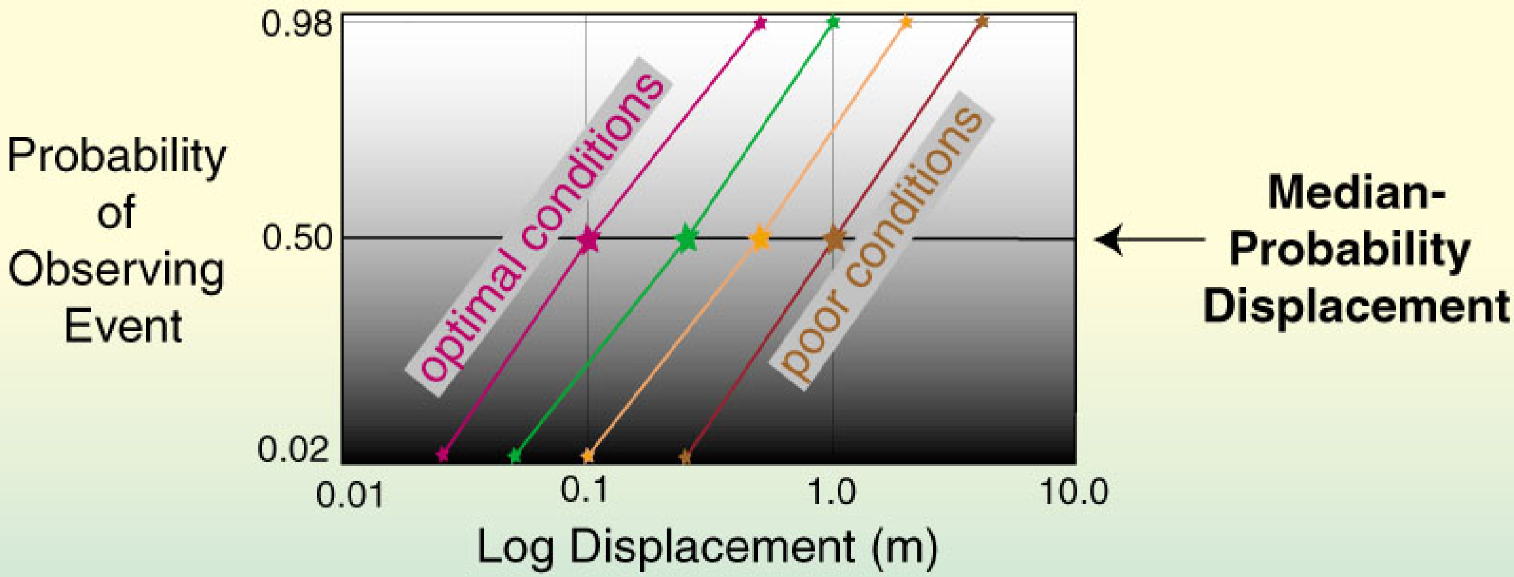
Median-Probability Displacement

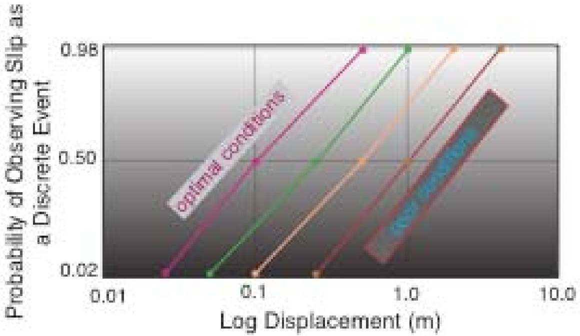
0.1 m
- Historical record of earthquakes

0.25 m
- Well-bedded stratigraphy and individual event horizons (deposition ≥ events)

0.5 m
- Poorly or complexly bedded stratigraphy
- Compound colluvial wedges/ superimposed event horizons (deposition < events)
- Progressive lateral offset of closely-spaced features

1.0 m
- Massive, poorly exposed, or poorly preserved compound colluvial wedges
- Progressive displacement of geomorphic surfaces with age
- Progressive lateral offset of features separated along strike
- Faceted compound fault scarps

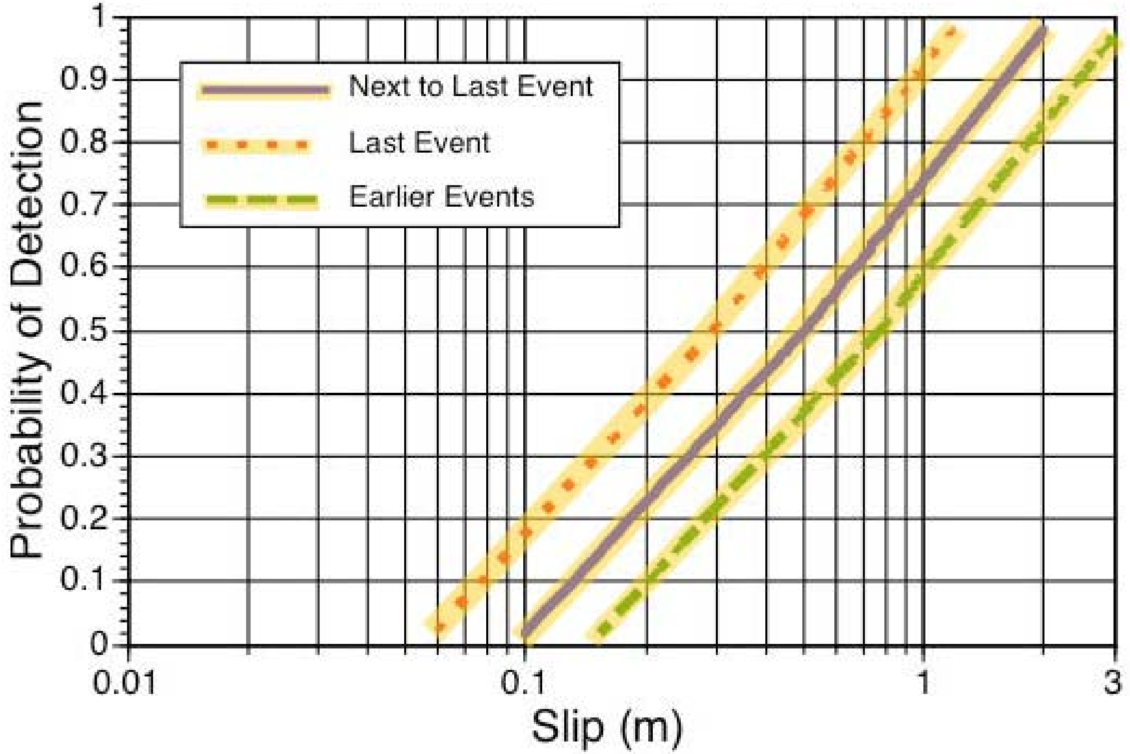




Probability of Detection Model

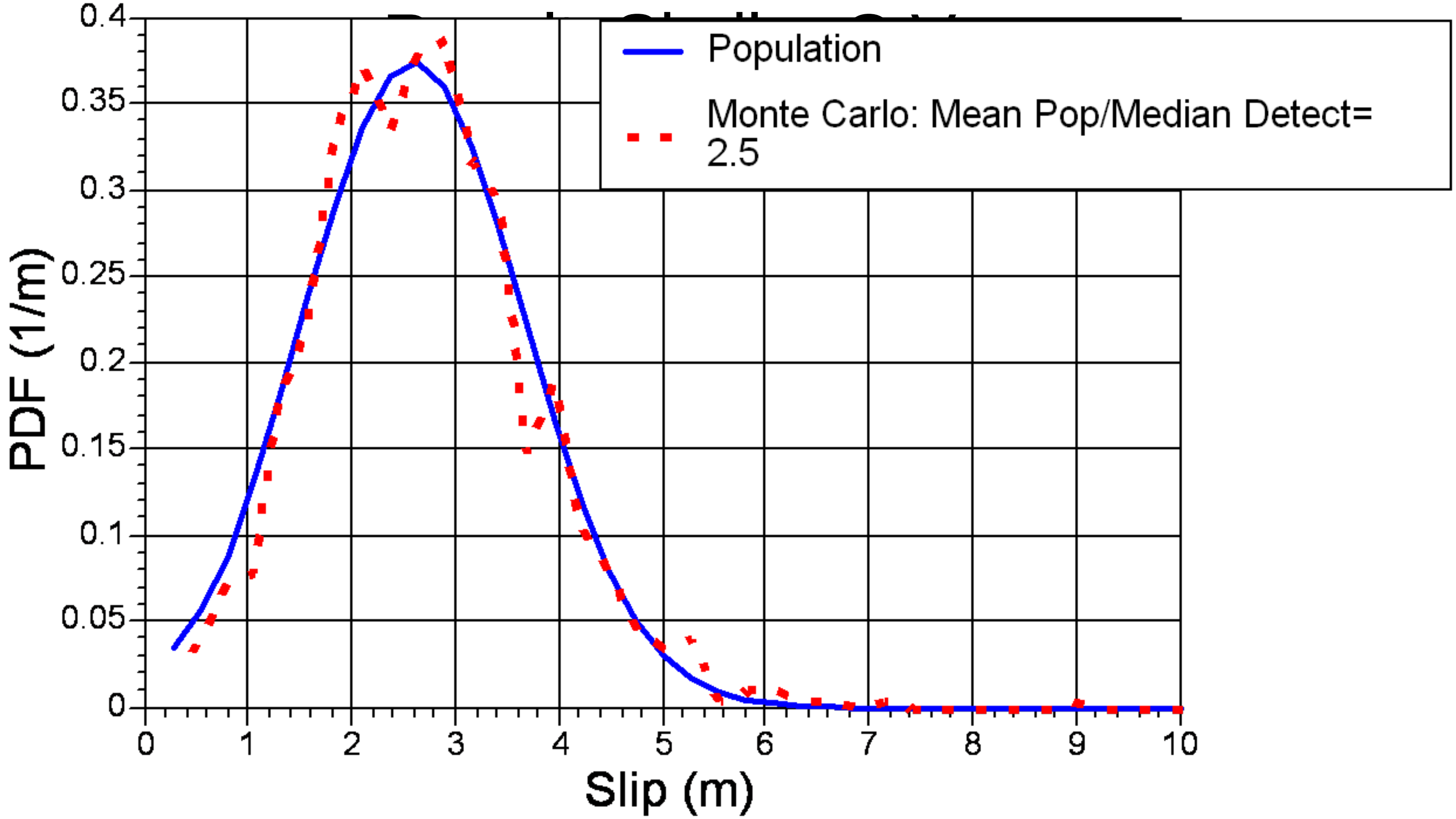
Example: 50% at 0.5m for next to last event

This leads to observed rates of position of smallest slip



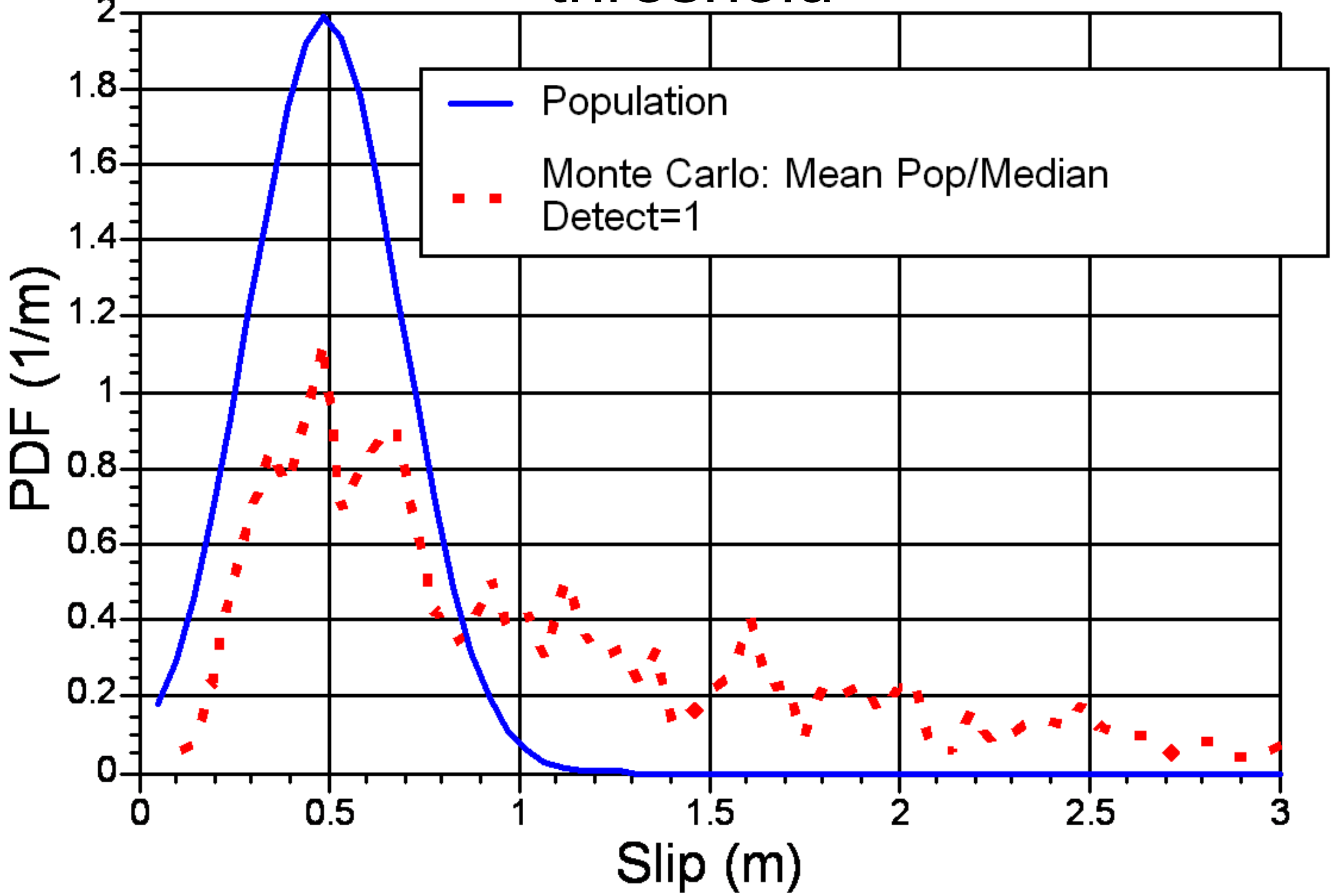
Effect of Probability of Detection

Example: mean slip is 2.5 times detection threshold



Effect of Probability of Detection

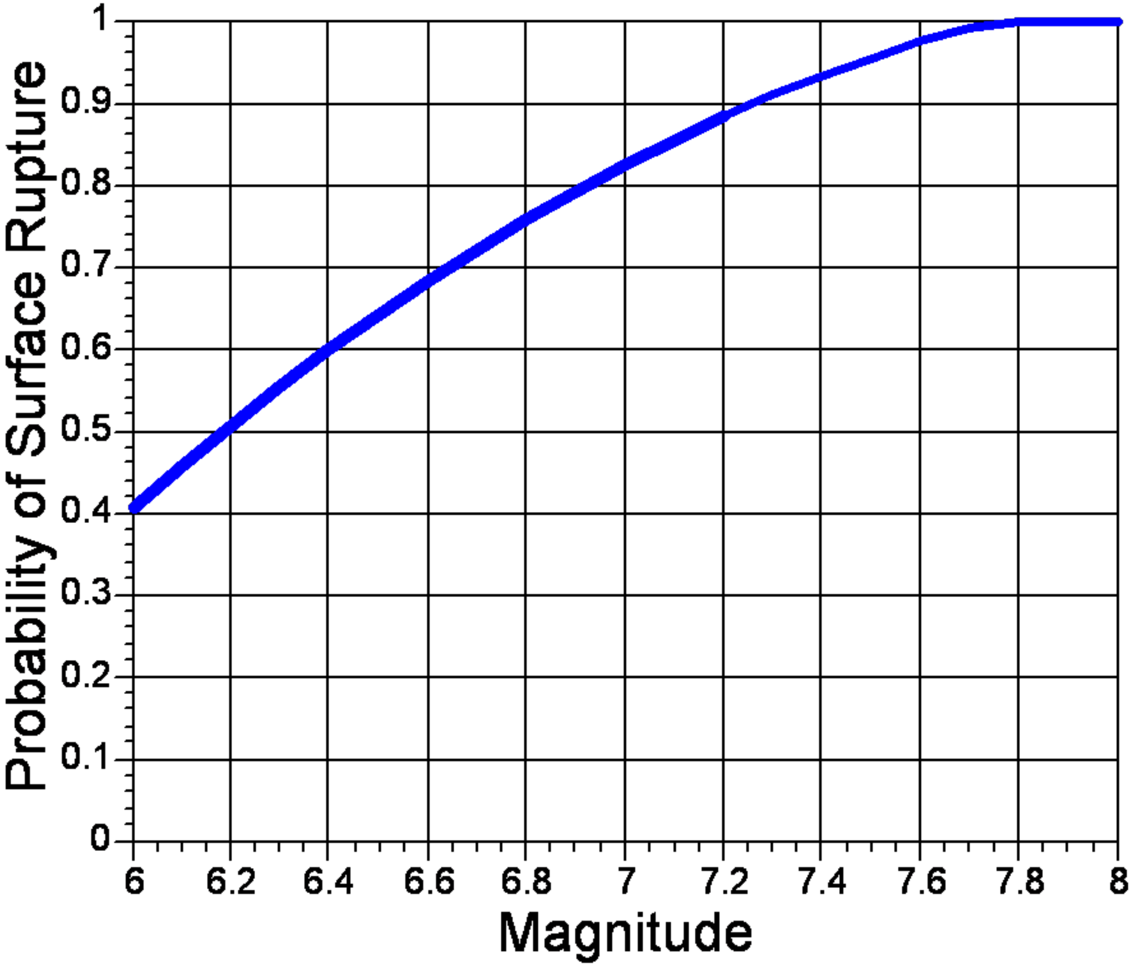
Example: mean slip is close to detection threshold



Modeling Variability in Slip at a Point

- Forward Modeling of expected observations of slip at a point
  - Prob (M) (from mag recurrence model)
  - Prob (rupture to surface given M)
  - Prob (rupture past site given Rup Length(M))
  - Prob (amount of surface slip given M)
  - Prob (detection) including effect of adding slip from non-detected events to the detected events
- Magnitude recurrence models
  - Truncated exponential
  - Youngs & Coppersmith Characteristic
  - Max Mag = 7.5, MinMag = 6.0

Probability of Surface Rupture (modified from IGNS, 2003)



Modeling Variability in Slip at a Point

- Forward Modeling of expected observations of slip at a point
  - Prob (M) (from mag recurrence model)
  - Prob (rupture to surface given M)
  - Prob (rupture past site given Rup Length(M))
  - Prob (amount of surface slip given M)
  - Prob (detection) including effect of adding slip from non-detected events to the detected events
- Magnitude recurrence models
  - Truncated exponential
  - Youngs & Coppersmith Characteristic
  - Max Mag = 7.5, MinMag = 6.0

Amount of Surface Slip

- Average Displacement
  - Use Wells and Coppersmith for all fault types
  - log(AD) = -4.8 + 0.69M ± 0.36 (±0.82 ln units)
- Variation in Displacement along Strike
  - Use results from (Hemphill-Haley and Weldon, 1999)
  - Sigma along strike approx 0.7 natural log units
- Total standard deviation of slip-at-a-point
  - Sqrt(0.82^2+0.70^2)= 1.07

Modeling Variability in Slip at a Point

- Forward Modeling of expected observations of slip at a point
  - Prob (M) (from mag recurrence model)
  - Prob (rupture to surface given M)
  - Prob (rupture past site given Rup Length(M))
  - Prob (amount of surface slip given M)
  - Prob (detection) including effect of adding slip from non-detected events to the detected events
- Magnitude recurrence models
  - Truncated exponential
  - Youngs & Coppersmith Characteristic
  - Max Mag = 7.5, MinMag = 6.0

C. V. from Modeling Results

Case 1: Using full Slip Variability for given M

Slip with 50% chance of detection in next to last event	Truncated Exponential C.V.	Y&C Characteristic C.V.
0.1 m	1.55	1.33
0.25 m	1.39	1.26
0.5 m	1.17	1.14
1.0 m	0.94	0.98
2.0 m	0.86	0.87

C. V. from Modeling Results

Case 2: Using reduced Variability for given M (reduced to 0.3 natural log units)

Slip with 50% chance of detection in next to last event	Truncated Exponential C.V.	Y&C Characteristic C.V.
0.1 m	0.71	0.44
0.25 m	0.64	0.42
0.5 m	0.68	0.48
1.0 m	1.06	0.78
2.0 m	1.13	0.98

Conclusions from Forward Modeling

- Variability of slip at a point must be much smaller than expected using global models.
- The Y&C characteristic magnitude-frequency model gives C.V. values similar to observed values if small variability in slip for a given magnitude is used.
- The truncated exponential magnitude-frequency model gives C.V. values much larger than observed even with reduced variability in slip for a given magnitude.