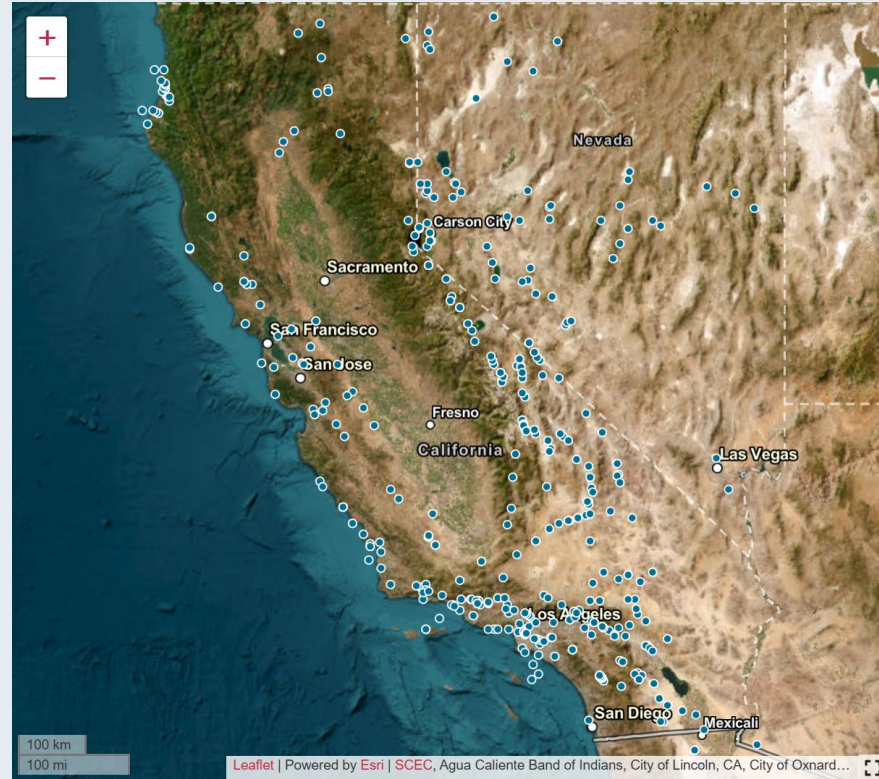


Why We Need a Slip Rate Database and More Than One Rate Per Fault



Scott Marshall
Appalachian State University



June 2, 2026

UNREST Workshop, Pismo Beach, CA

GSRD Homepage | <https://southern.scec.org/research/gsrđ>

New GSRD Explorer | <https://moho.scec.org/gsrđ-explorer/>

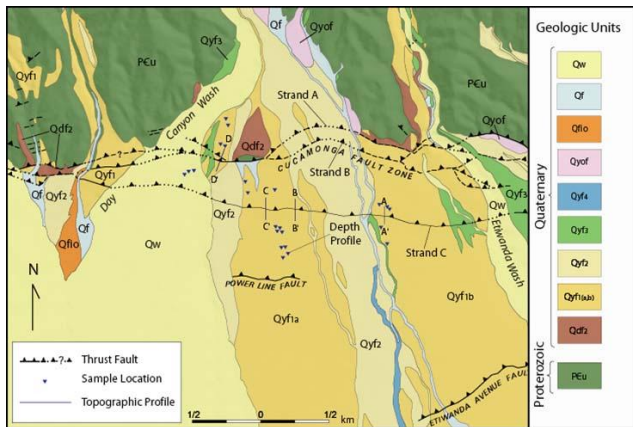


USGS NSHM23 Slip Rate Database

Fault slip rates are crucial to seismic hazard assessments

- NSHM23 produced a slip rate database “EQGeoDB”
- V3 is current: Hatem et al. (2023)
- Slip rates and metadata provided in .txt file
- Great resource!

Prevents modelers from having to locate & interpret existing slip rate sites



The screenshot shows the USGS ScienceBase-Catalog page for the dataset "Earthquake geology inputs for the U.S. National Seismic Hazard Model (NSHM) 2023 (western U.S.) (ver. 3.0, December 2023)". The page includes a navigation bar with "ScienceBase-Catalog", "Communities", and "Help". The main content area displays the dataset title, a "View" button, and a "Dates" section with the following information: Publication Date: 2021-01-21, Revision: 2022-02-25, Last Revision: 2023-12-21. A "Citation" section provides the full citation for Hatem et al. (2023). A "Summary" section describes the data release. A "Child Items" section lists "NSHM23_EQGeoDB_v3" and "NSHM23_FSD_v3". A "Contacts" section lists the authors. A "Map" section shows a map of the western U.S. with a blue box indicating the dataset's coverage area. A "Spatial Services" section provides a ScienceBase WMS URL. A "Communities" section lists the dataset as a child item for the 2023 National Seismic Hazard Model. An "Associated Items" section lists related datasets and workshops. A "Tags" section is also present.

NSHM23 EQGeoDB v3 (Hatem et al., 2023)
<https://www.sciencebase.gov/catalog/item/651d97a6d34e44db0e2d44e7>



The SCEC Geologic Slip Rate Database (GSRD)

SCEC Geologic Slip Rate Database

<https://www.scec.org/research/gsr/>

New GSRD Explorer (not publicly released yet)

<https://moho.scec.org/gsr-explorer/>

Geologic field-based estimates of fault slip rates

A subset of the NSHM23 and UCERF3

Direct hyperlinked references (where available)

Updated in 2025

94 new slip rates; 5 updated rates

The SCEC Geologic Slip Rate Database Explorer currently consists of a set of georegistered sites where geologic estimates of fault slip rates have been estimated. To simplify browsing and downloading the Slip Rate Database, the explorer below provides a two-dimensional map-based view of the Slip Rate Database. The Slip Rate Database can be queried based on fault or site name, and minimum/maximum slip rate, or by individually clicking on points on the map. Once sites are selected, they are added to the list below the map interface with selected metadata shown. The complete 27 columns of metadata for all selected sites can be downloaded (in .csv format) with the "Download All Data" button. Refer to the user guide for more details and usage instructions.

Choose Dataset : **Slip Rate Data**

High Rate Select a range on the High Rate slider or enter the two boundaries in mm/yr

CFM6.0 GFM

Slip Rate Site (fault | site)

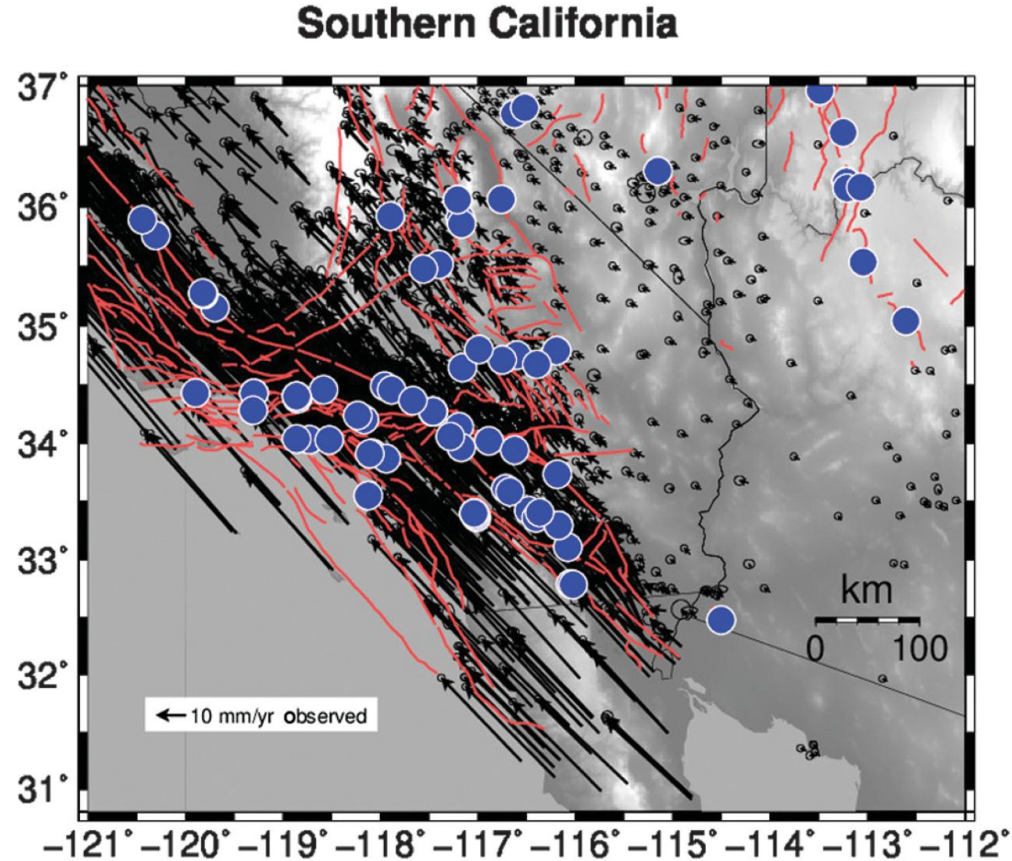
- San Jacinto (Coyote Creek) | per Bilisniuk and others
- Elniñore (Glen Ivy) | Wild Rose Ranch
- San Gregorio (north) | Ano Nuevo
- Algodones | Upper Mesa
- Almanor | East Benner Creek
- Anaheim | approx centroid
- Antelope Range | Profile 2&3
- Antelope Valley | per Sarmiento and others. (2011)
- Ash Hill | Ash Hill
- Battle Creek | per Page and Renne (1994)
- Benton Spring (south) | Mina1-BS
- Bettles Well - Petrified Springs | PS
- Big Lagoon | BM1
- Black Rock | Trench 1
- Blackwater | per Oskin and Iriondo (2004)
- Breckenridge | Oak Tree
- Butte Mountains | Profile 1-4 midpoint
- Calaveras (north) | Levden Creek

ID	Fault Name	Site Name	Rate Type	Low Rate (mm/yr)	High Rate (mm/yr)	CFM6 Object	References	<input type="button" value="DOWNLOAD ALL DATA"/>
----	------------	-----------	-----------	------------------	-------------------	-------------	------------	--

The Geologic Slip Rate Database Explorer showing slip rate sites colored by max slip rate (McGill, Marshall, Hatem, and Akçiz)

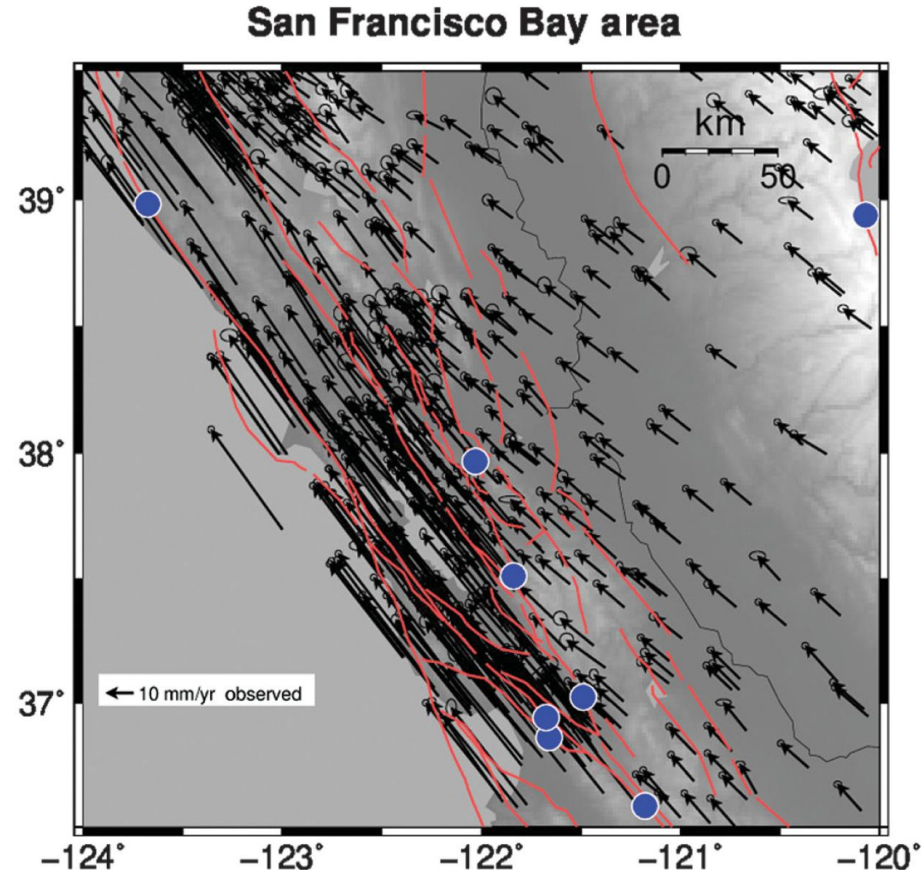
Many deformation models use geologic slip rates as constraints

- NSHM23 includes 4 deformation models
- All NSHM23 models used geologic slip rates as constraints in inversions
- Many faults were unconstrained by data



Many deformation models use geologic slip rates as constraints

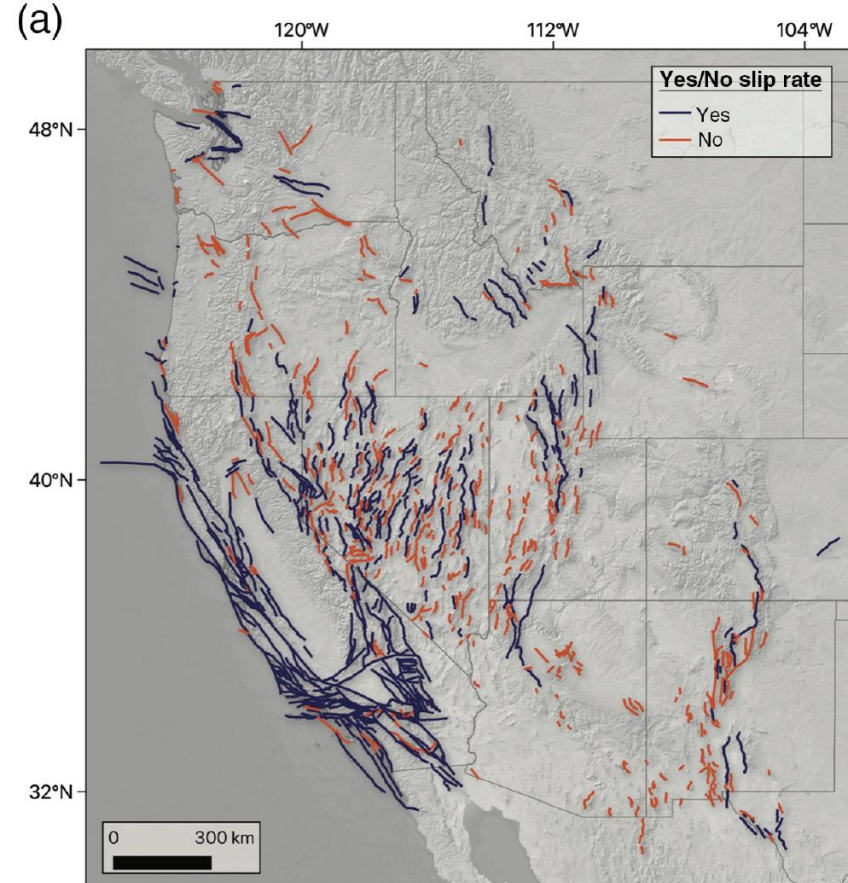
- NSHM23 includes 4 deformation models
- All NSHM23 models used geologic slip rates as constraints in inversions
- Many faults were unconstrained by data



USGS NSHM23 Slip Rates

Fault slip rates are crucial to seismic hazard assessments

- Many faults have no geologic slip rate study
- NSHM23 assigned slip rate PDFs and QFFD slip rate categories
- Compared “geologic” strain rates to geodesy

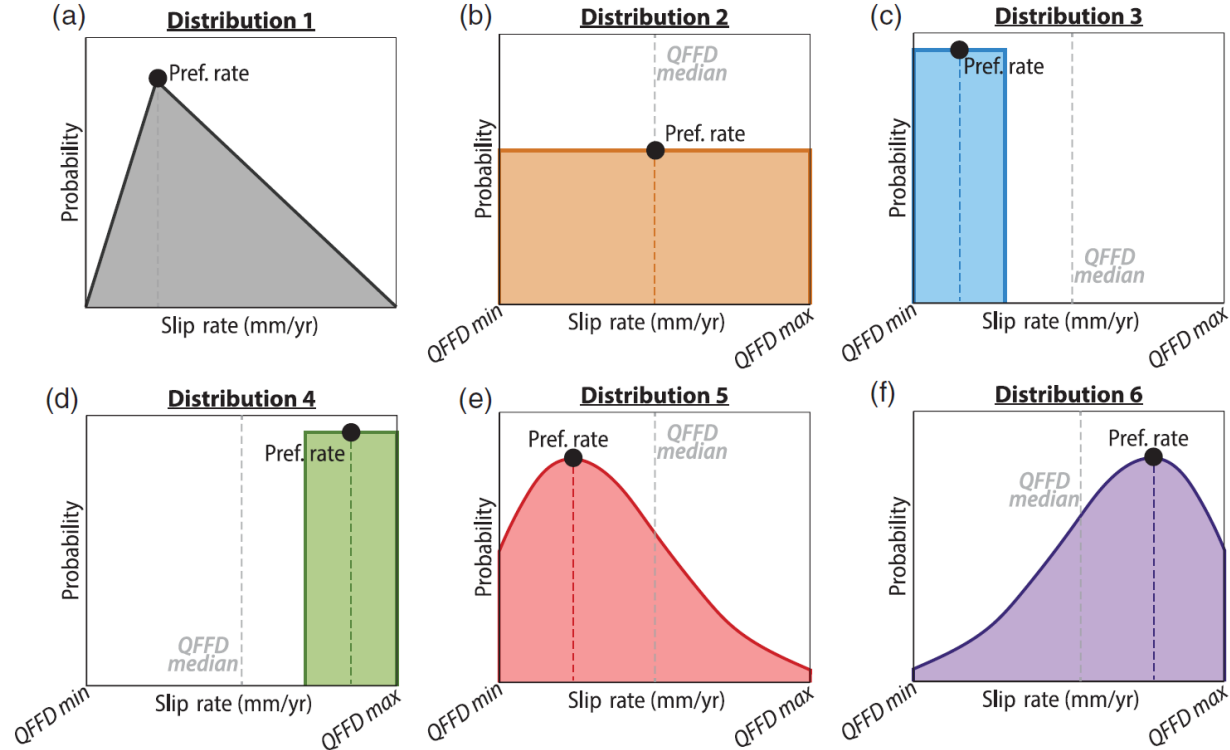


Hatem et al. (2022, SRL)

USGS NSHM23 Slip Rates

Geologic slip rates have epistemic uncertainty and inconsistent uncertainties

- NSHM23 assigned slip rate PDFs and QFFD slip rate categories
- Compared “geologic” strain rates to geodesy



Slip Rate Probability Distribution Functions (PDFs)
from Hatem et al. (2022, SRL)

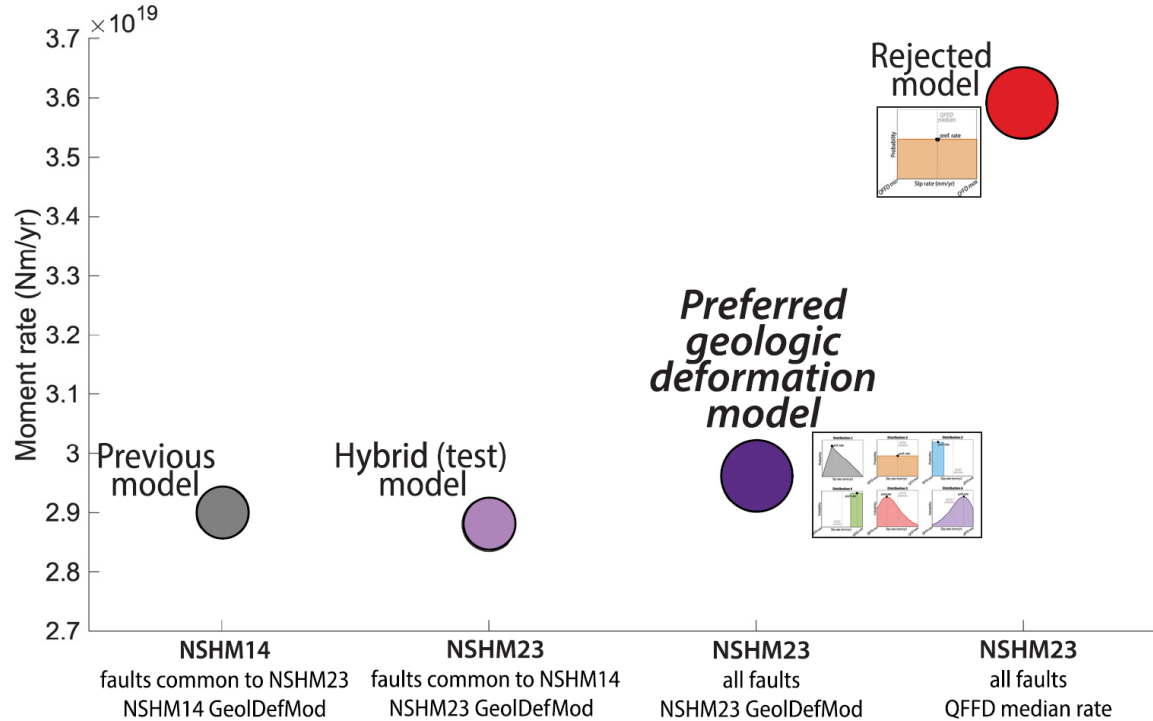
USGS NSHM23 Slip Rates

Median geologic slip rates appear to overestimate moment rate

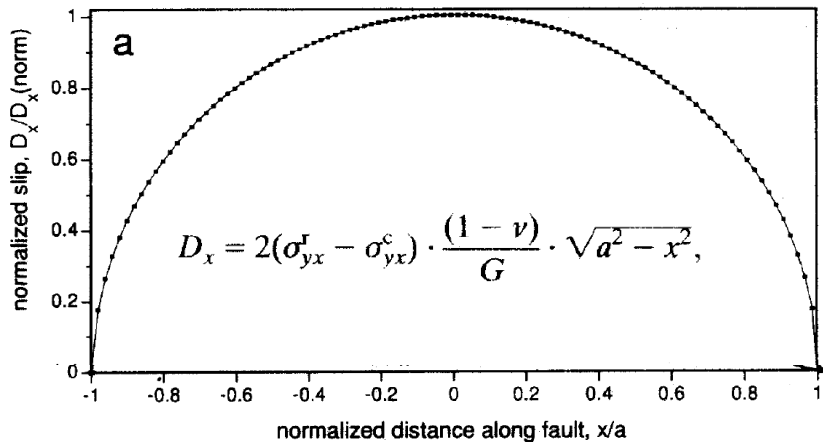
- Why?

Let's look at predictions from models and earthquake data

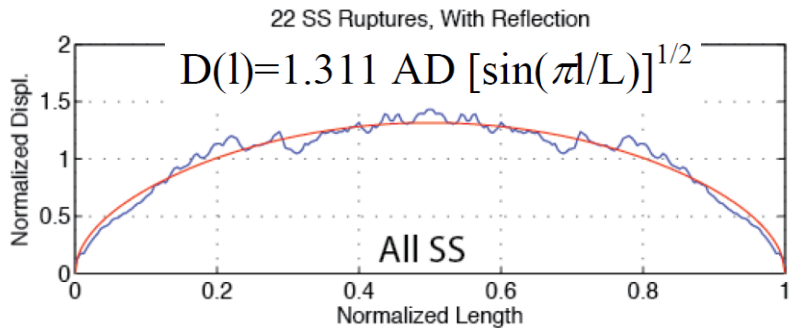
- 1) Fracture mechanics & empirical fits to coseismic slip distributions
- 2) 2D & 3D mechanical model predictions of slip



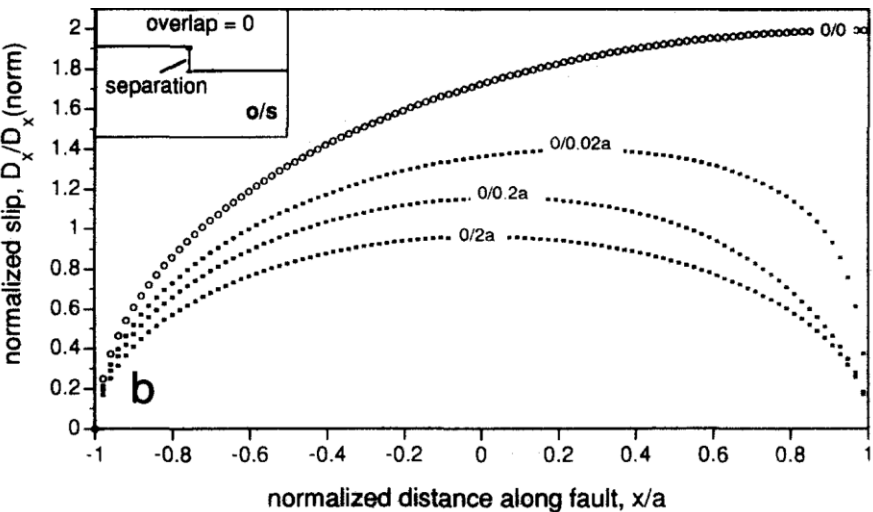
Slip Rate Probability Distribution Functions from Hatem et al. (2022, SRL)



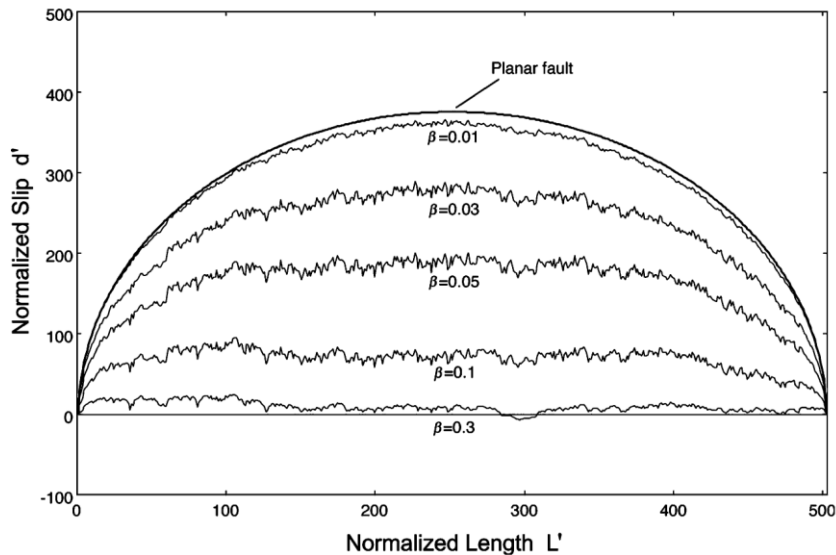
Bürgmann et al. (1994, JSG): Analytical slip distribution function (elliptical)



Biasi et al. (2013, UCERF3 appendix F): *sinsqrt* empirical slip function



Bürgmann et al. (1994, JSG): Interacting faults produce different slip distributions



Dieterich & Smith (2009, PAGEOPH): 2D Models of slip along fractally rough faults

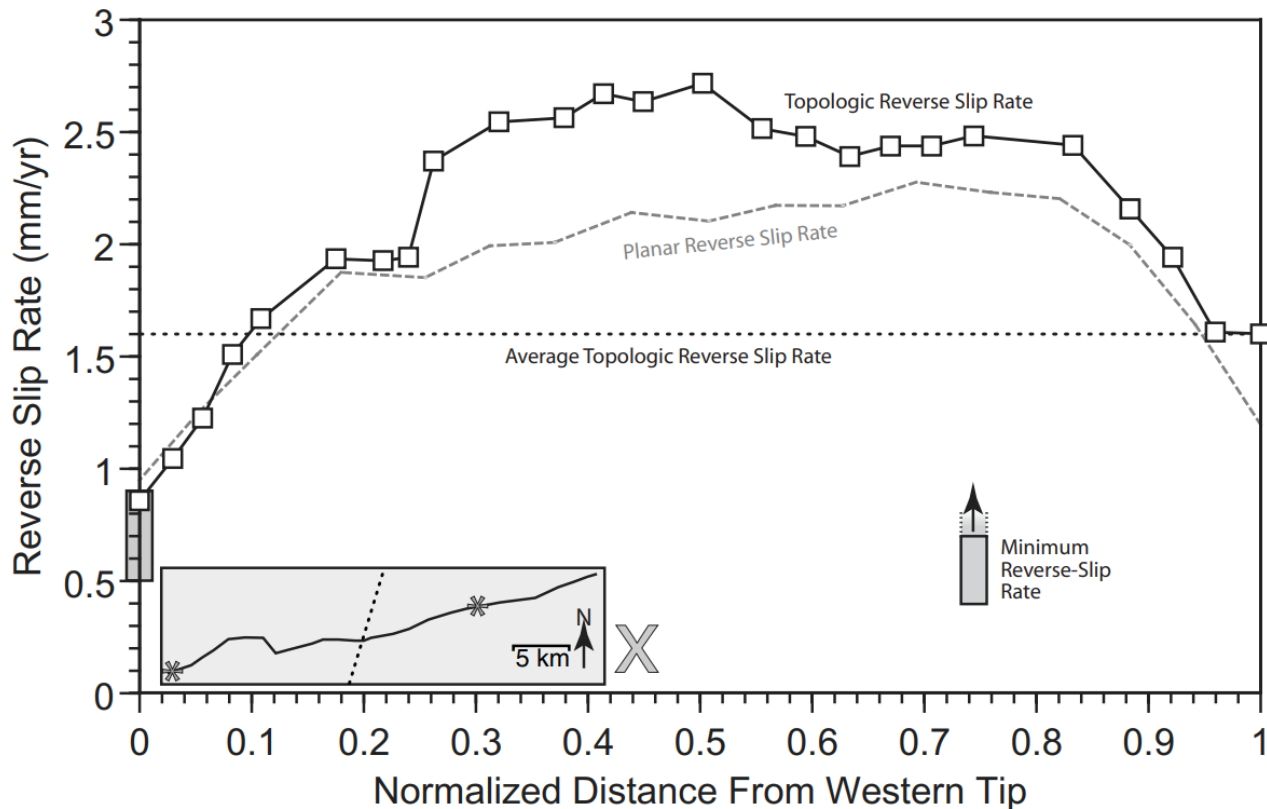


Slip Rates From 3D Mechanical Models

Marshall et al. (2008, BSSA)

<https://doi.org/10.1785/0120070159>

- Full 3D model of western Transverse Ranges
- Based on the SCEC CFM
- Includes fault interactions
- Compared planar and non-planar fault models
- Estimated slip rates and full 3D distributions



Marshall et al. (2008, BSSA):
3D Model of slip along the surface trace of the Simi-Santa Rosa fault

Ventura Fault: Near-Surface Slip Distribution

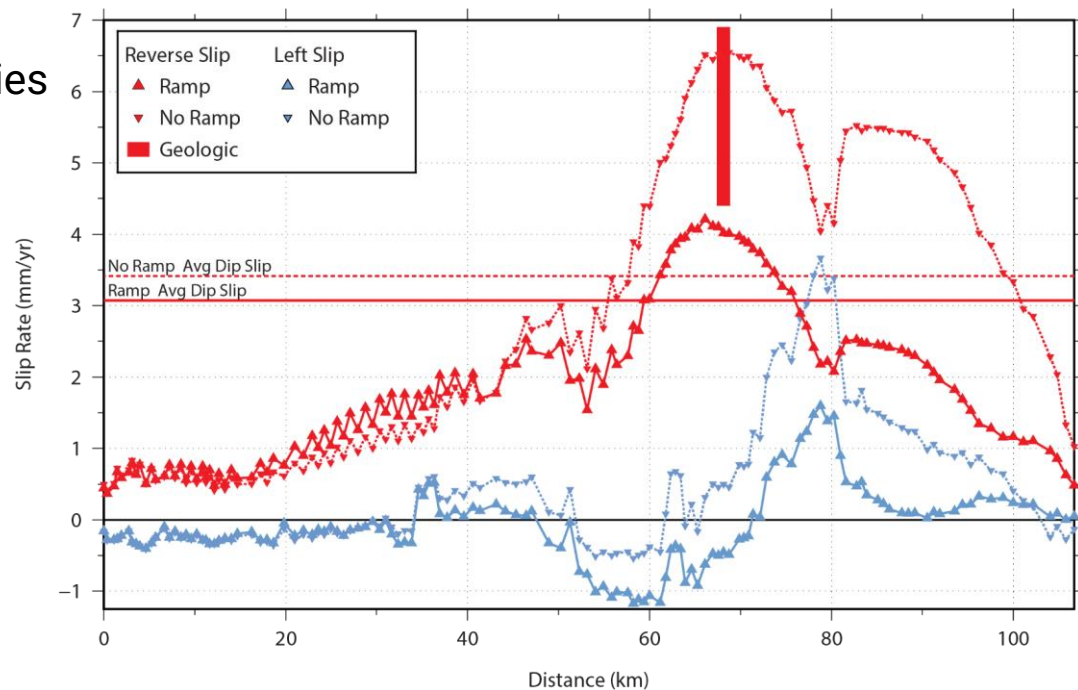
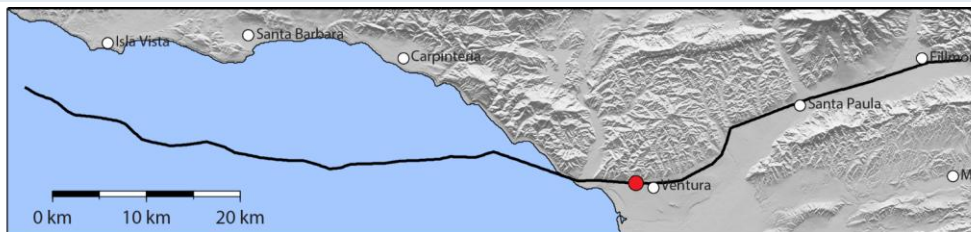
Marshall et al. (2013, JGR)

<https://doi.org/10.1002/jgrb.50312>

- Full 3D model of western Transverse Ranges.
- Tested different Ventura fault geometries

Slip Rate Distributions

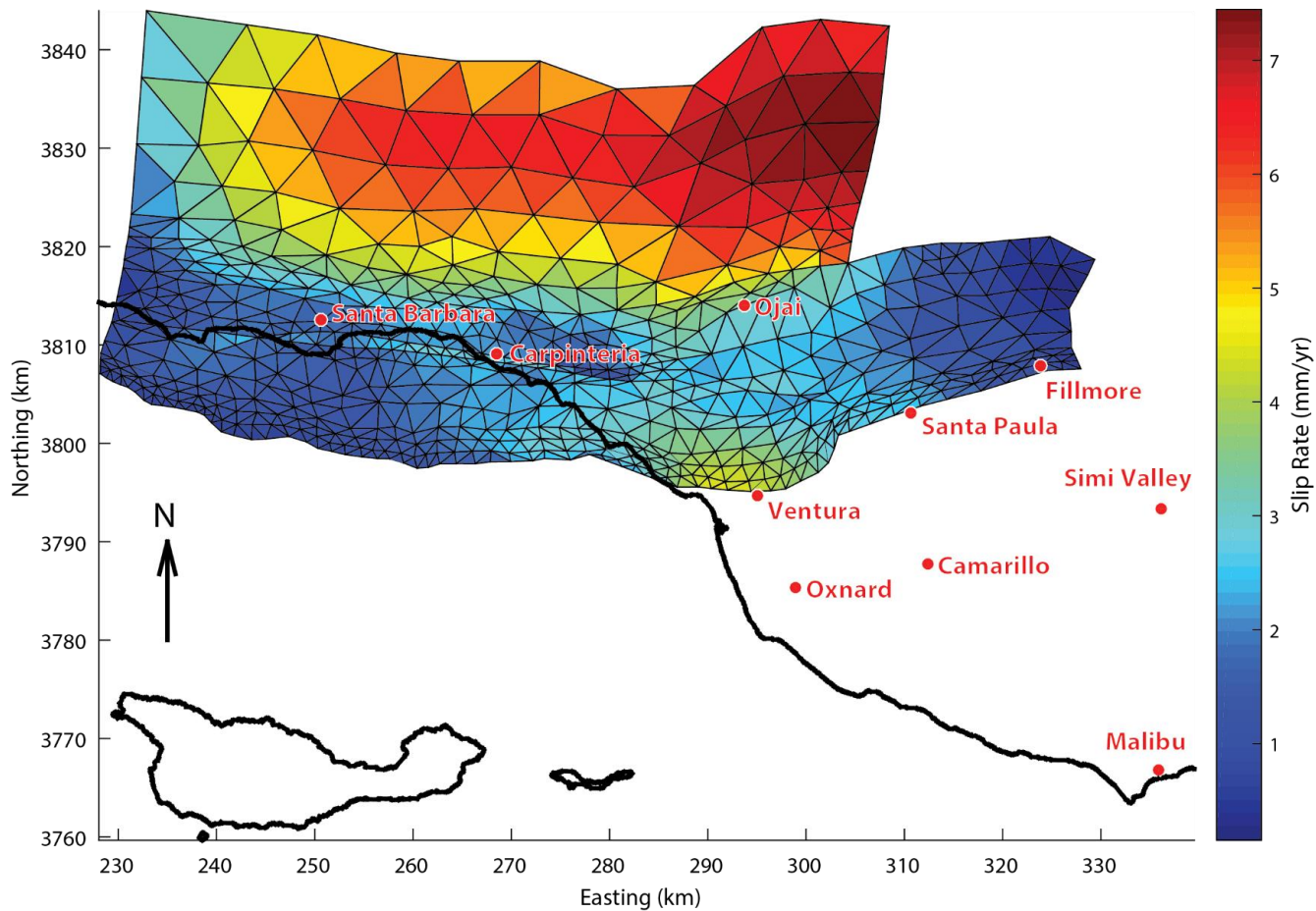
- Avg slip rates are similar
- Surface slip greatly differs
- Hubbard et al. site at location of max surface slip and above avg slip rates
- Ramp-flat-ramp model preferred



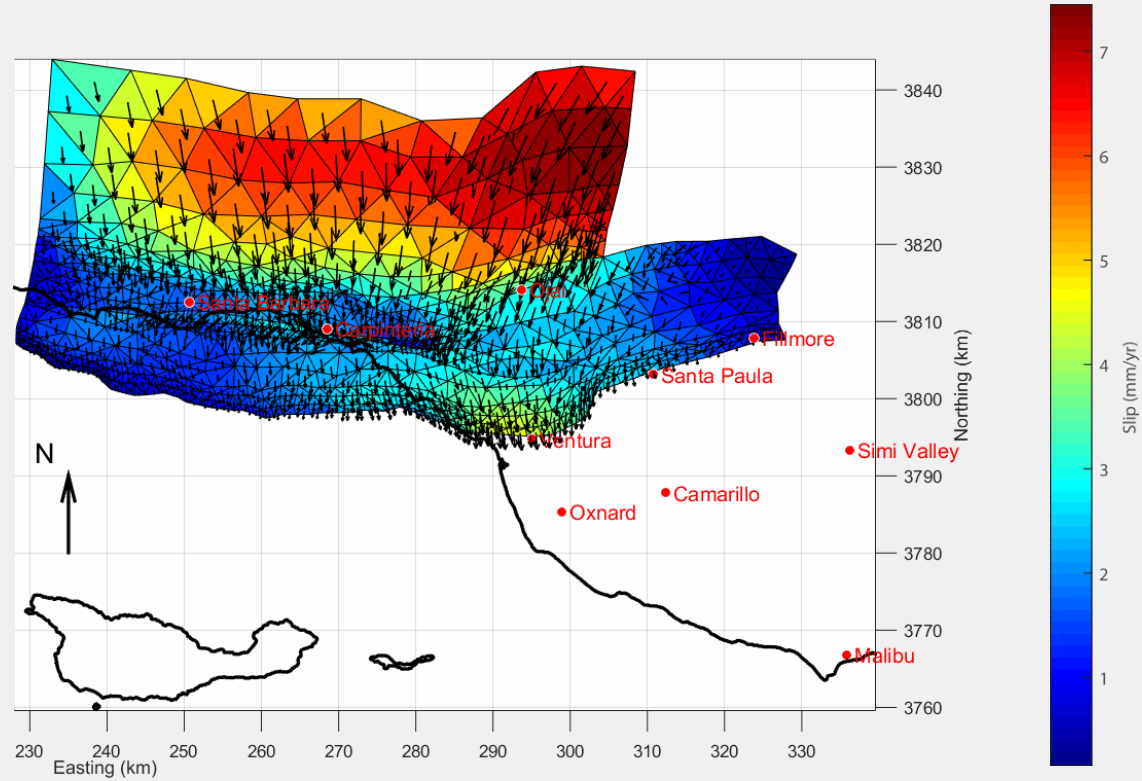
Ventura Pitas Point Fault: 3D Slip Distribution

3D Slip Distribution is Complex

- Fast rates near coast where large paleo-uplift events have been found
- Max slip is on lower ramp at depth, which agrees with Hubbard et al., (2014)



Ventura Pitas Point Fault: 3D Slip Distribution



Geologic Sites May Overestimate Average Rates

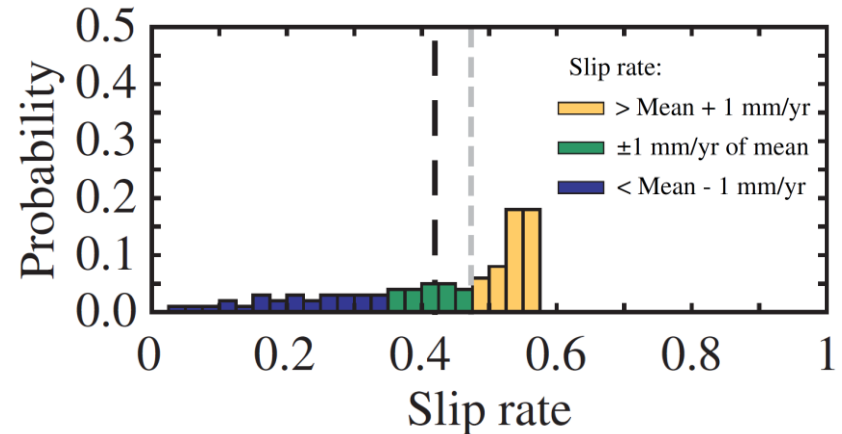
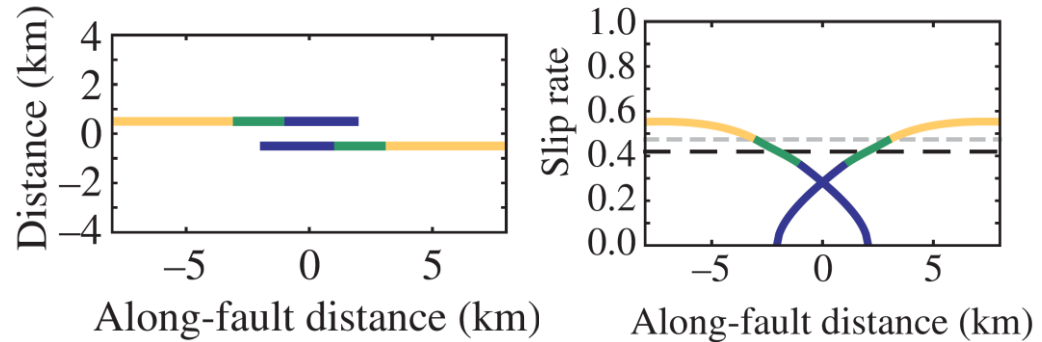
Resor et al. (2018, BSSA)

<https://doi.org/10.1785/0120170332>

- Tested toy models of strike-slip faults with and without stepovers.
- Modeled San Jacinto slip rate (17.5 mm/yr)

Conclusions:

- All models result in skewed distributions for which a randomly selected site has a higher probability of sampling a slip rate that exceeds the mean.
- For most configurations, individual point measurements are unlikely ($p < 0.5$) to yield a slip rate within ± 1 mm=yr of the mean.



From Resor et al., (2018, BSSA). Black=mean, Gray=median



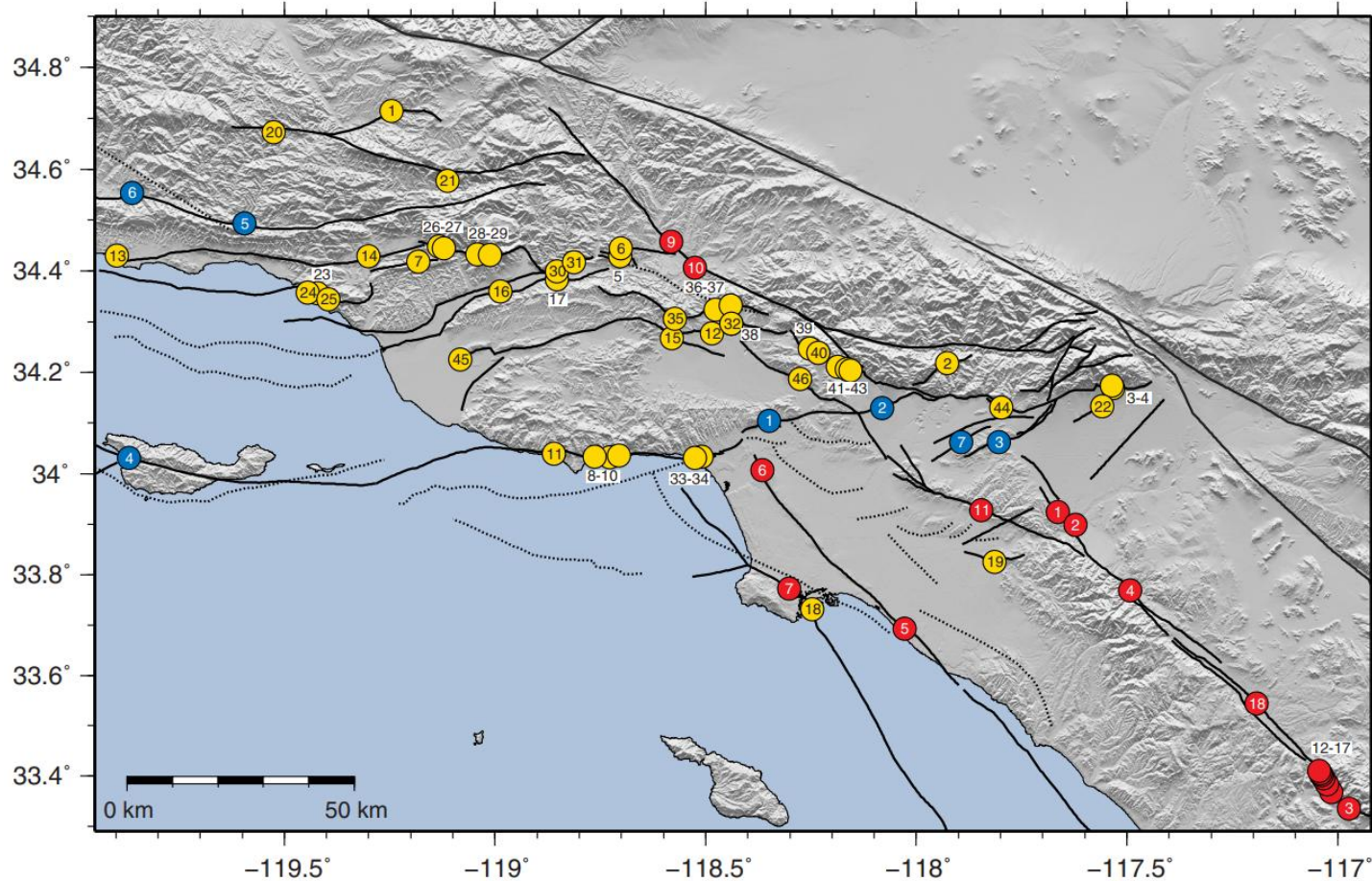
Are Slip Rate Sites at “Average” Locations

Devine et al. (2022,
SRL)

Compared 3D BEM
models to geologic
slip rates

**Individual point
estimates of slip**

- 44 reverse slip
- 26 strike-slip
- 70 total





Are Slip Rate Sites at “Average” Locations

Do geologic study sites occur at “average” rate locations?

Above 1:1 line

Site is above average rate

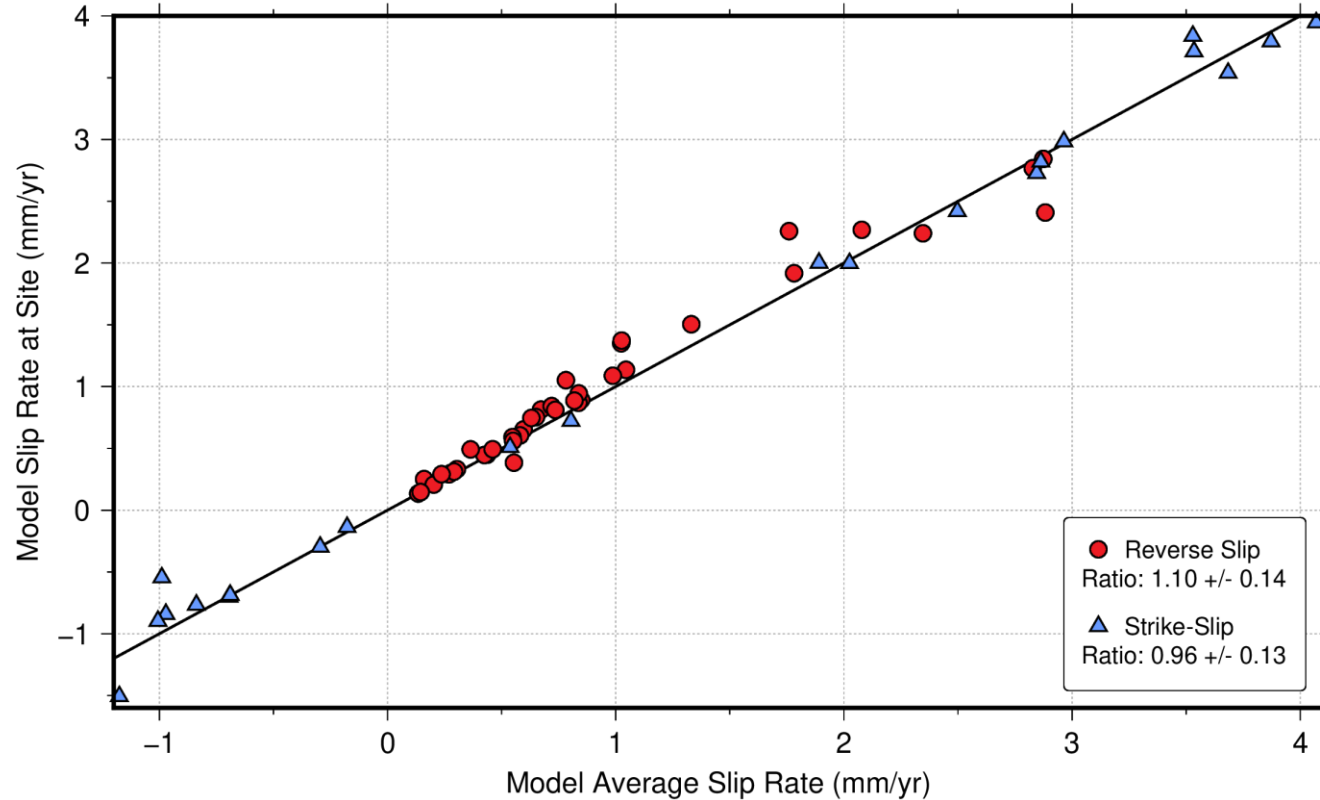
$$\text{Ratio} = \frac{\text{Rate at Site}}{\text{Avg Rate}}$$

Reverse Slip Ratio

1.10 +/- 0.14

Strike-Slip Ratio

0.96 +/- 0.13



Calculated using BEM models of Devine et al. (2022)

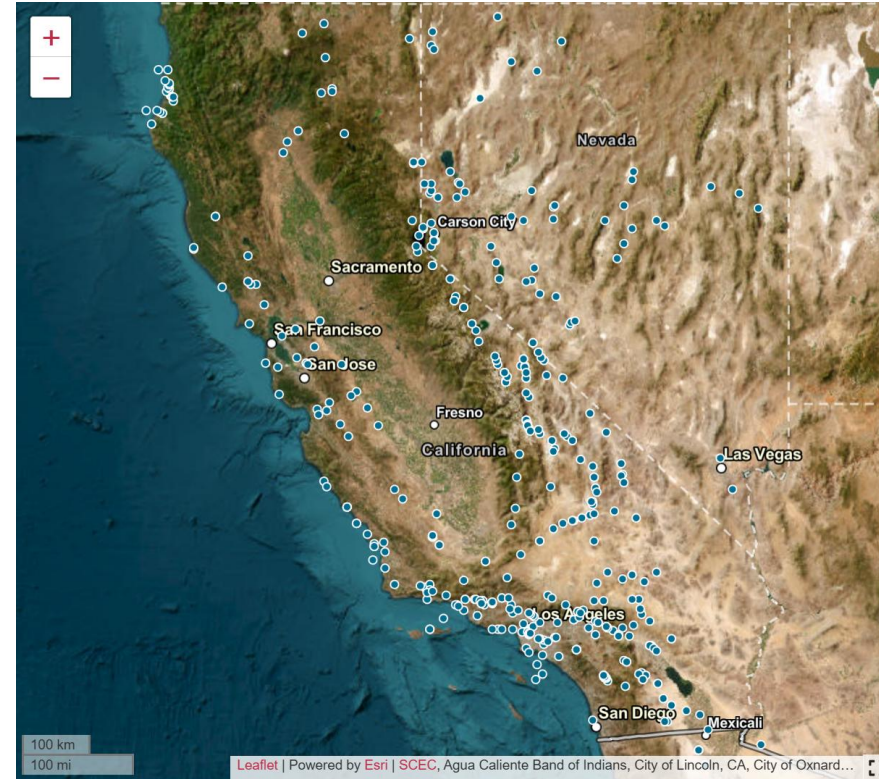
Conclusions & Moving Forward

A geologic slip rate database GSRD is needed

- For modelers & seismic hazard assessments
- Must be periodically updated & accessible
- Can help define areas that are under-studied

Many slip rates are needed for all faults

- 3D slip distributions are complex
- Individual point-based studies tend to overestimate slip
- Comparison with 3D models can put point-based estimates of slip into 3D context



GSRD Homepage | <https://southern.scec.org/research/gsrđ>

New GSRD Explorer | <https://moho.scec.org/gsrđ-explorer/>