Lessons, Lore, and Legacies of the 1992 Landers Earthquake

SCEC.org/webinar/landers30

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Agenda

Mark Benthien, Southern California Earthquake Center
Welcome and Introduction

Dr. Susan Hough, United States Geological Survey
1992 Landers Earthquake Sequence: Science Lessons Learned

Division Chief James Topoleski, San Bernardino County Fire Department
Emergency Response Following the Landers Earthquake

Local Perspectives

Gary Daigneault, News Director, Morongo Basin Broadcasting Corp (Z107.7FM)
Chris Gubler, Gubler Orchids
Gino Prudholm, The Church of Jesus Christ of Latter-Day Saints

Prof. Gregory Beroza, Stanford University
30 Years of Earthquake Science: Legacies of Landers

Q&A

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The 1992 Landers Earthquake Sequence: Lessons

Susan Hough
US Geological Survey,
Pasadena, California

USGS science for a changing world

SCEC AN NSF+USGS CENTER

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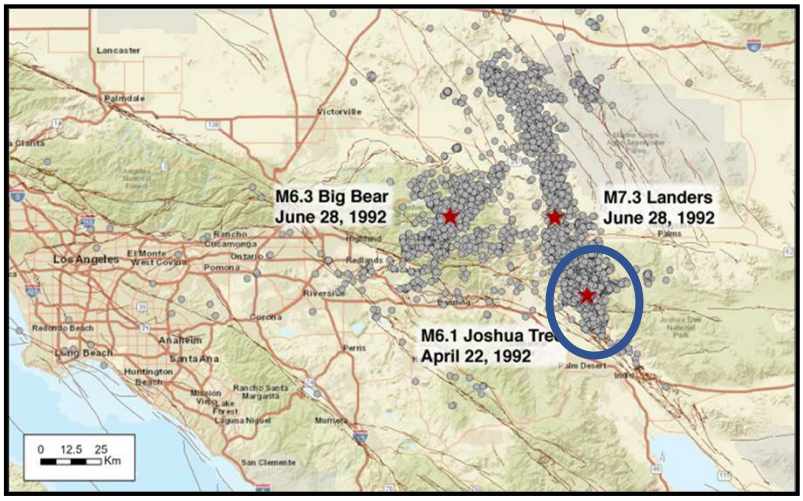
22* April 1992 Joshua Tree Earthquake



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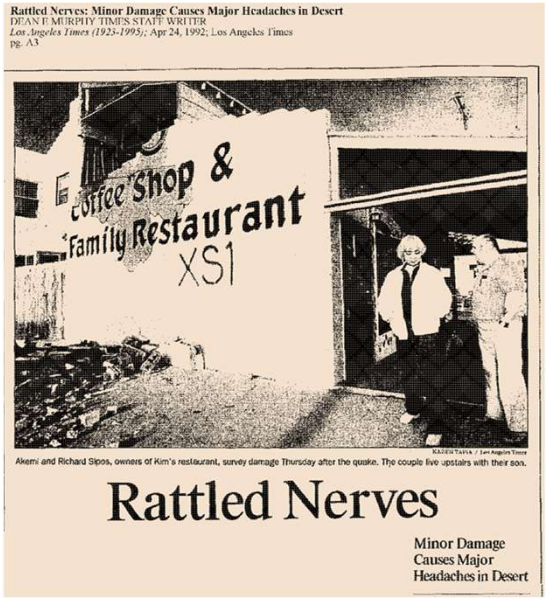
"Rattled Nerves"

"I just want to go back to Germany," said German tourist Liane Drees, who spent the night in a Desert Hot Springs motel with her eyes on the door.



Rattled Nerves: Minor Damage Causes Major Headaches in Desert
DEAN E. MURPHY TIMES STAFF WRITER
Los Angeles Times (1923-1995); Apr 24, 1992; Los Angeles Times
pg. A3

KAREN TAKA / Los Angeles Times

Akemi and Richard Sipos, owners of Kim's restaurant, survey damage Thursday after the quake. The couple live upstairs with their son.

Rattled Nerves

Minor Damage Causes Major Headaches in Desert

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Earthquake Response

- March 1, 1992: Start working at USGS in Pasadena
- April 23, 1992: Felt earthquake
- April 24, 1992: Deployment
  - Morongo Valley dense array
- June 23, 1992: Visit to NY
- June 27, 1992: Return to California
- June 28, 1992, 4:57am -- Earthquake!
- > June 28: Data retrieval & analysis

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High alert

SCEDC Southern California Earthquake Data Center

Home | Cite the SCEDC | Recent Earthquakes | Earthquake Info | EQ Catalogs | Access Data | FAQ | About

Earthquake Information

Chronological Earthquake Index

Joshua Tree Earthquake

TYPE OF FAULTING: right-lateral strike-slip
TIME: April 22, 1992 / 9:50:23 pm PDT
LOCATION: 33° 57.6' N, 116° 19' W 18 km (11 miles) east of Desert Hot Springs 29 km (18 miles) north of Indio
MAGNITUDE: M_W6.1
DEPTH: 12.4 km

Preceeded by a magnitude 4.6 foreshock -- which, by itself, caused a stir -- the Joshua Tree earthquake raised some alarms due to its proximity to the San Andreas fault. A San Andreas Hazard Level B was declared following this quake, meaning that a 5 to 25% chance existed for an even larger earthquake happening along the San Andreas fault within 3 days. That never happened, of course, but roughly two months and 6000 aftershocks later, the Landers earthquake broke the surface of the Mojave in the largest quake to hit

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Scientific Response

- Seismic network
- No surface rupture
- Portable seismometers
- Precursor to San Andreas event?

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28 June, 4:57am PST: Landers

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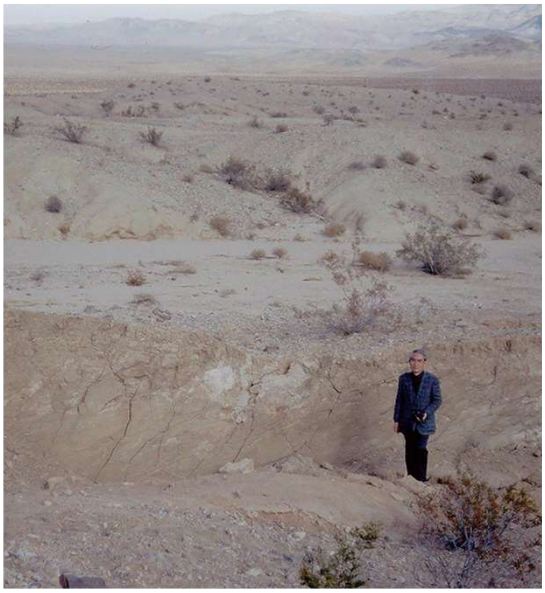

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Lessons from Landers

- Complexity of earthquake-earthquake interactions
- Remotely triggered earthquakes
- Complexity of earthquake ruptures

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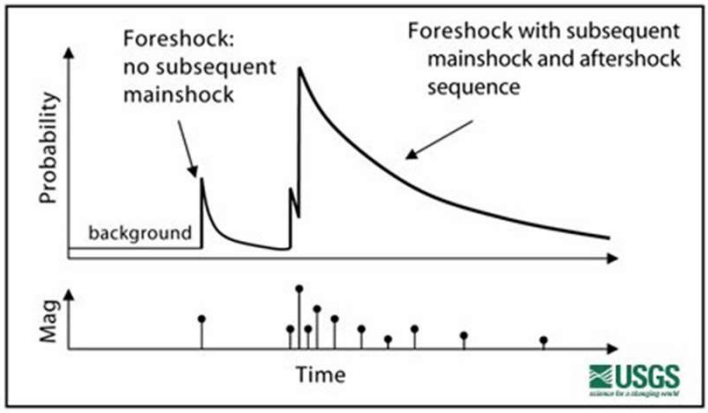
Foreshocks, Mainshocks, Aftershocks



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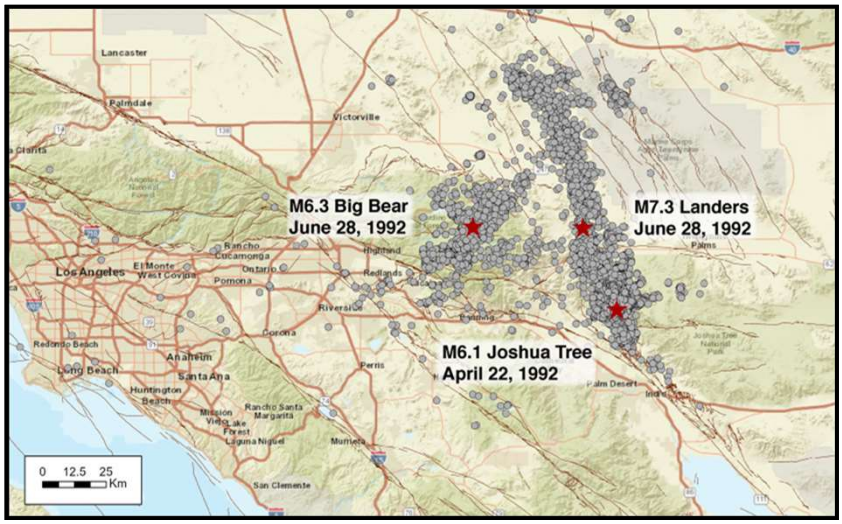
Mainshock→ foreshock ("Parent events")



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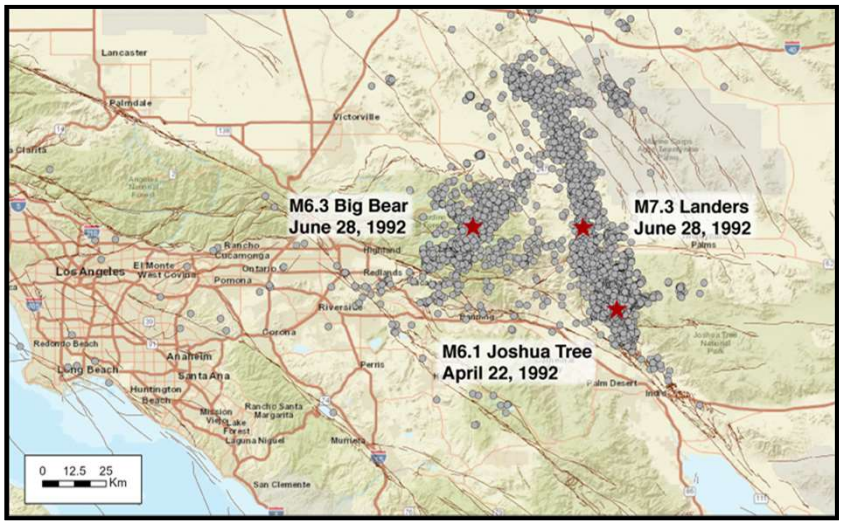
Big earthquakes → Big aftershocks



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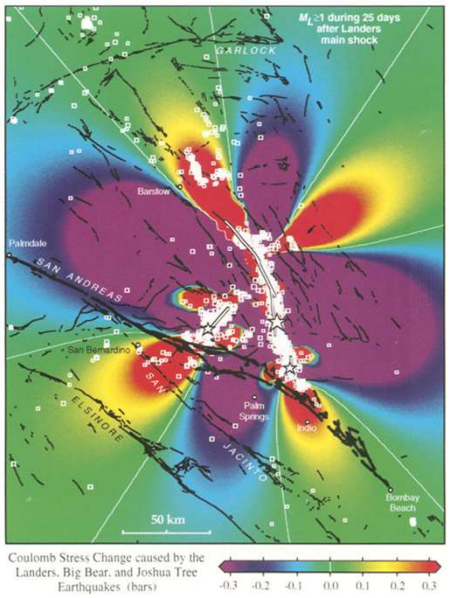
Aftershock Triggering

Earthquake rupture →
Static stress change



Ross Stein, et al.

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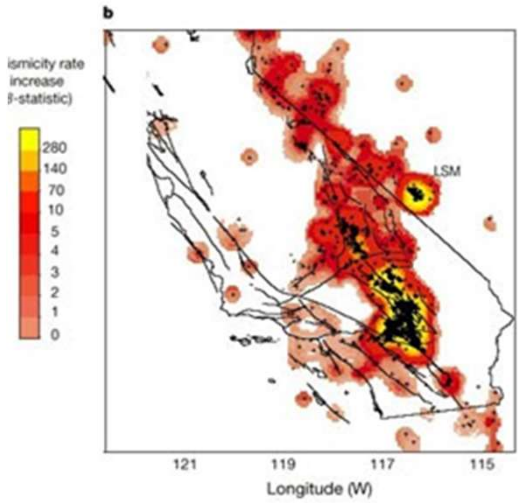
Remotely Triggered Earthquakes



Earthquake rupture → Dynamic stress change

Gomberg et al., Nature, 2001

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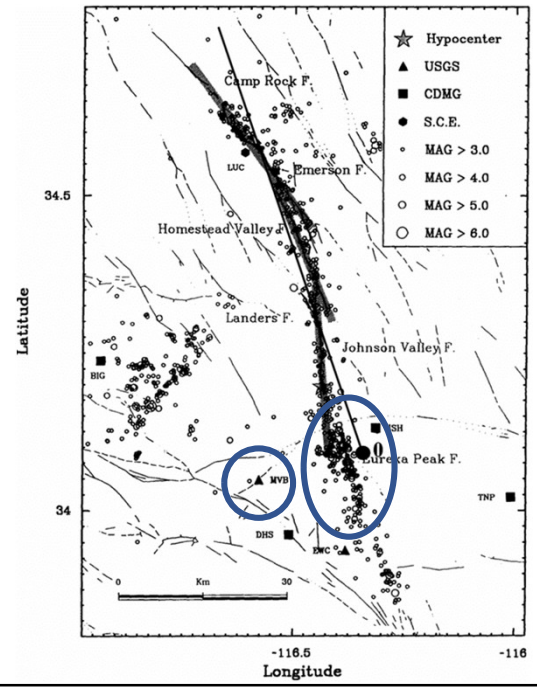
Rupture Complexity

- Johnson Valley – Landers – Homestead Valley – Emerson – Camp Rock faults
- Fault length → maximum earthquake size?



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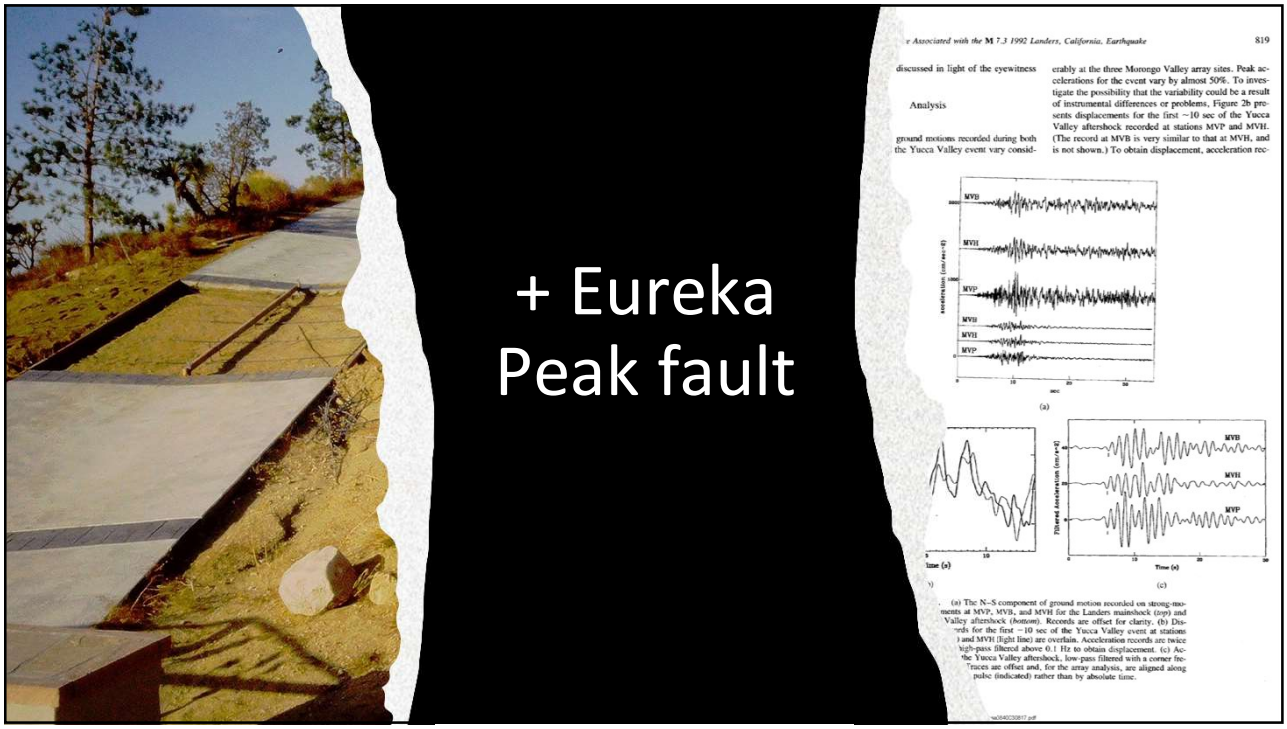

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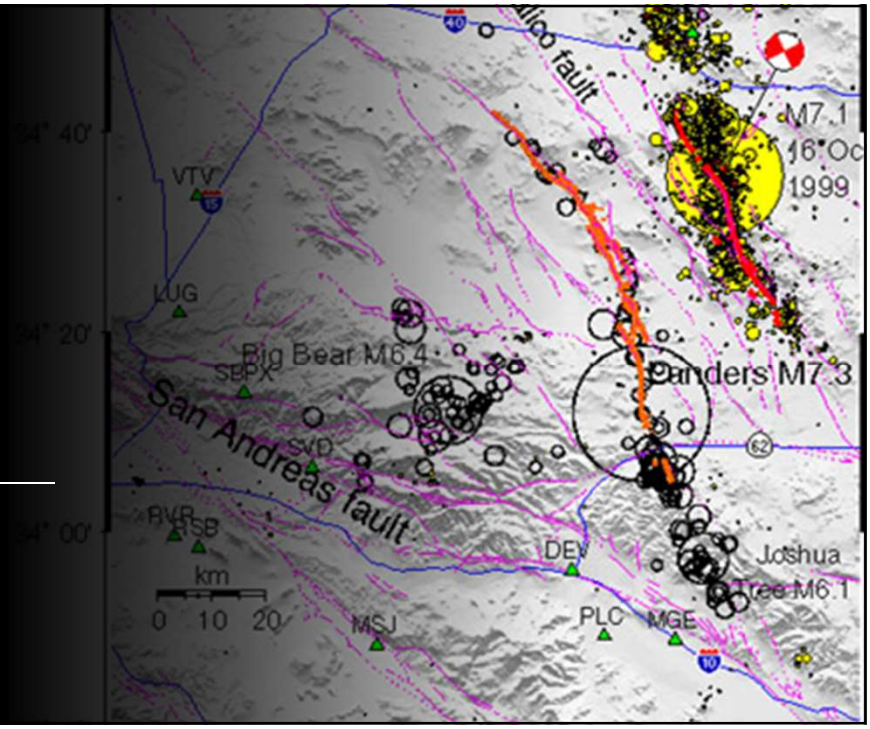
1999: The Mojave Awakens



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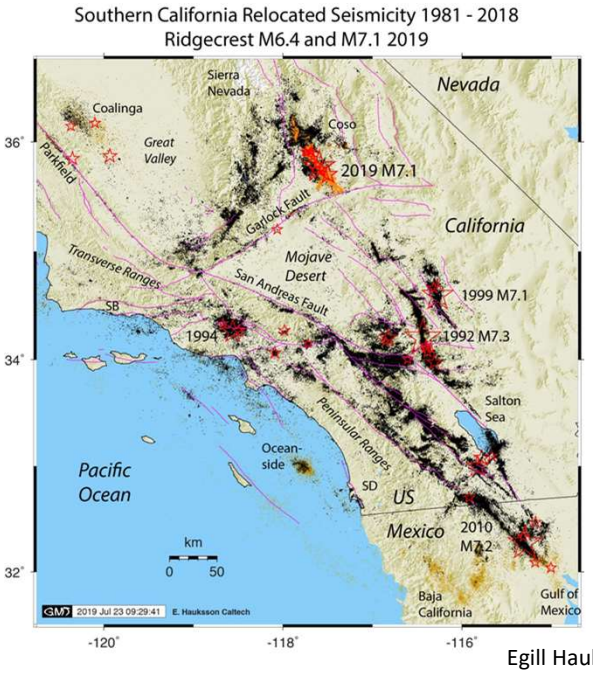
2019: Ridgecrest



Egill Hauksson

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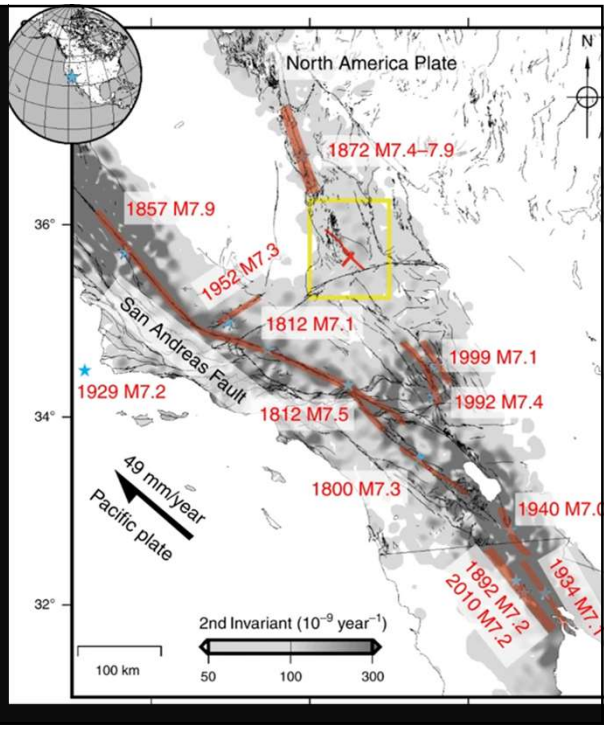
Lessons: Complexity

- Earthquake ruptures
- Earthquake-earthquake interactions
- Local and distant triggering
- Protracted sequences
- Plate boundary



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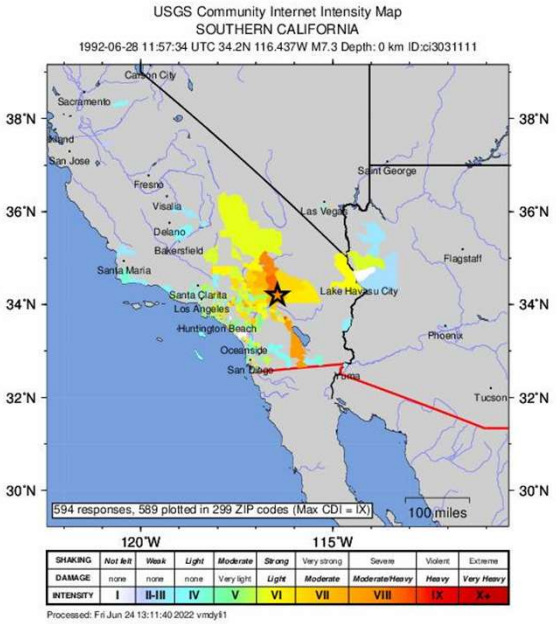
Did YOU Feel It?



https://earthquake.usgs.gov/earthquakes/eventpage/ci3031111/tellus

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Q&A

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Questions?
scecinfo@usc.edu

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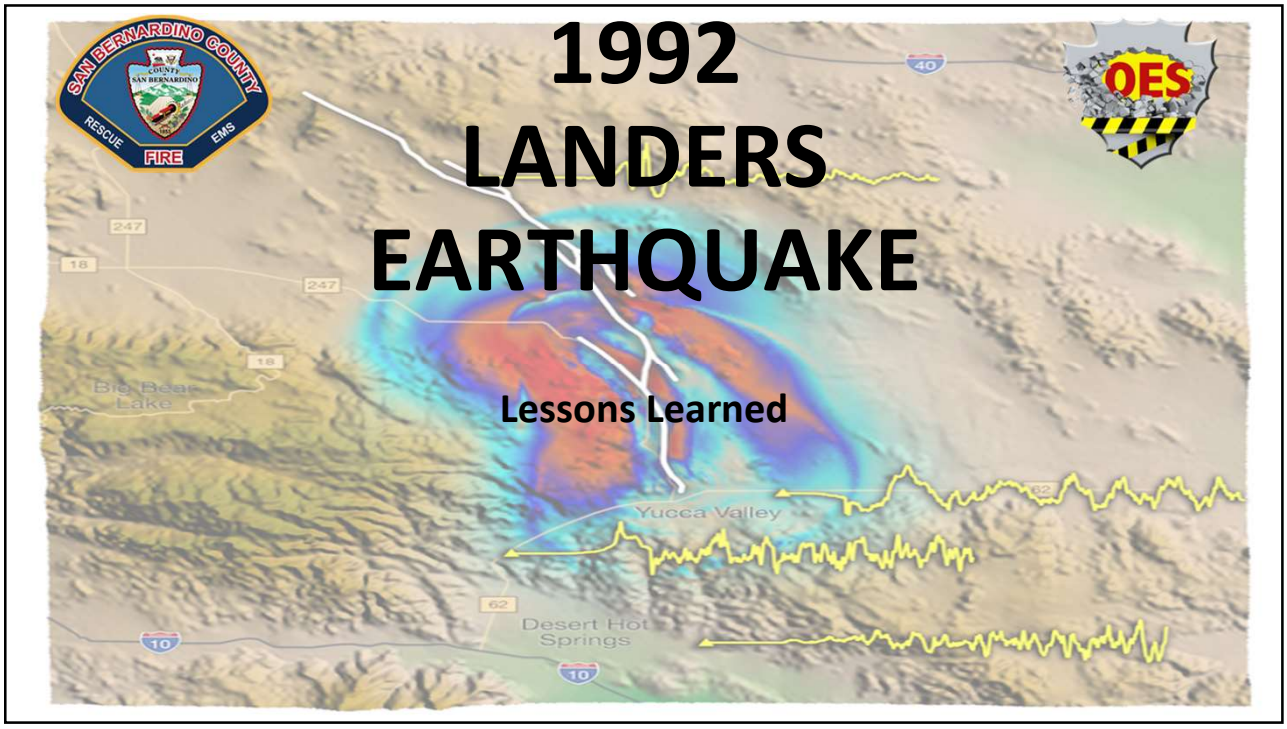

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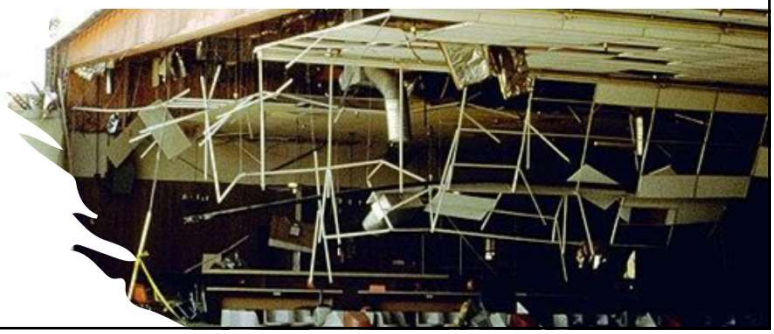
FIRE/USAR RESPONSE

Historical Perspective

- Response capability has changed over the past 30-years
- Operational Area Support
- Search and Rescue from fire service was strained
  - Big Bear Earthquake absorbed resources
  - Road network impacts
  - Water systems impacted rural environment
  - Specialized personnel and resources limited



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Lessons Learned

San Bernardino County Fire

- OES Regional USAR Task Force 6
- Communication System Improvements
- Large mobile water delivery systems
- Emergency Command Support
- Heavy Equipment Capability

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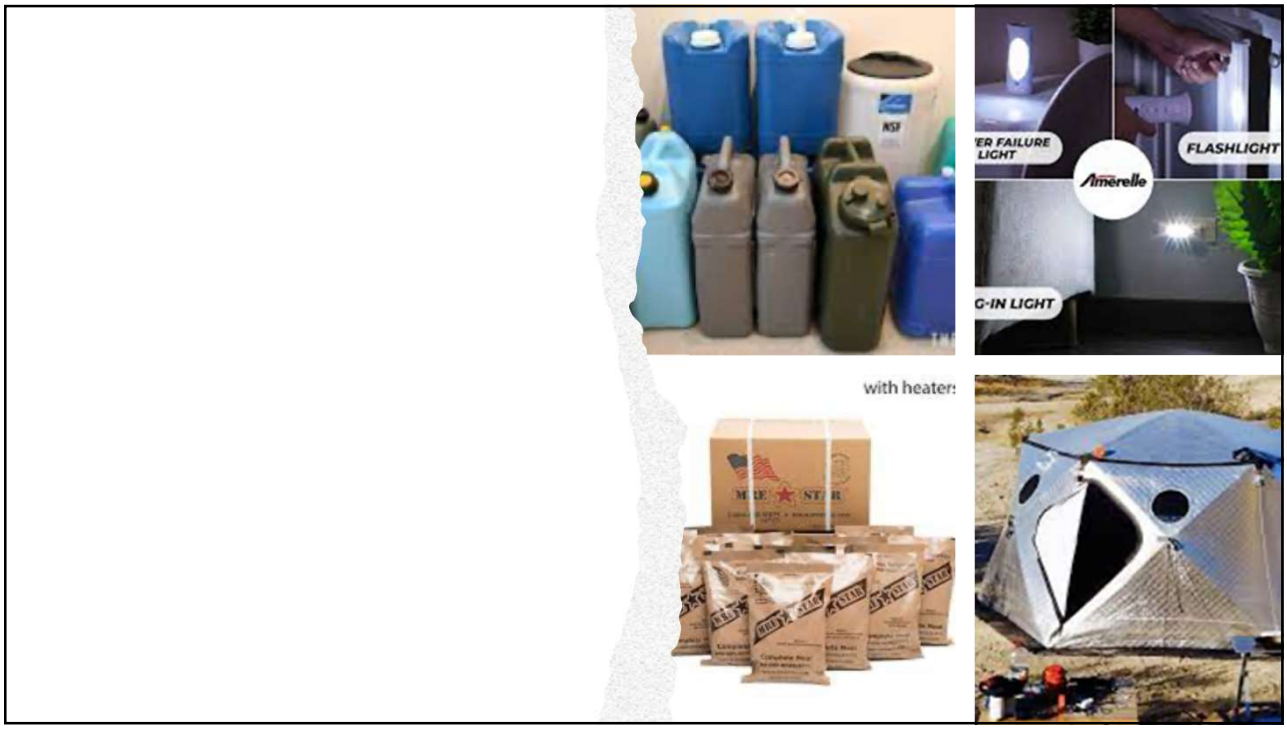

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scecinfo@usc.edu

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Agenda

Local Perspectives

Gary Daigneault, News Director, Morongo Basin Broadcasting Corp (Z107.7FM)
Chris Gubler, Gubler Orchids
Gino Prudholm, Church of Jesus Christ and Latter Day Saints

Have a short story to share?
Please write a short description in the "Q&A" tool and we may call on you to share.

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30 Years of Earthquake Science: Legacies of Landers

Gregory Beroza
Stanford University

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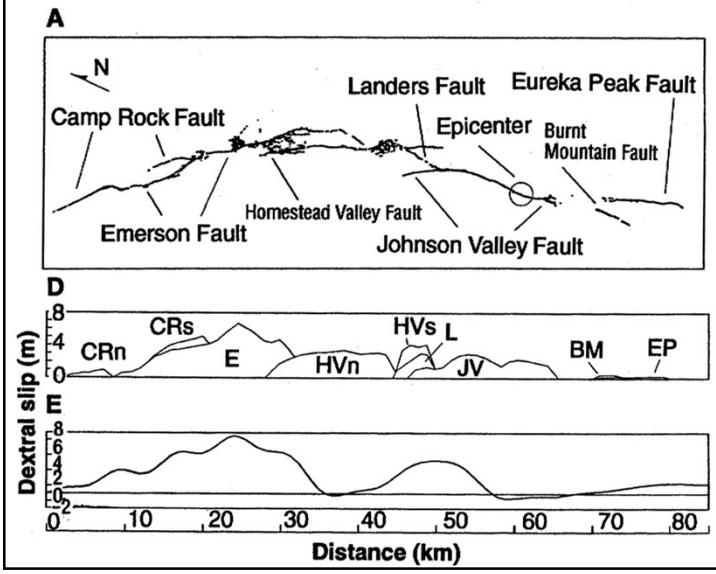
Fault Complexity and Earthquake Size



Earthquake Rupture:

- **Began on the Johnson Valley Fault**
- **Jumped to the Homestead Valley Fault**
- **Jumped to Camp-Rock/Emerson Fault**
- **Involved other faults to a lesser extent**
- **Stopped on a straight section of CR**

These observations overturned the assumption that earthquake size is primarily limited by fault segmentation.

***Sieh et al.* (1993)**

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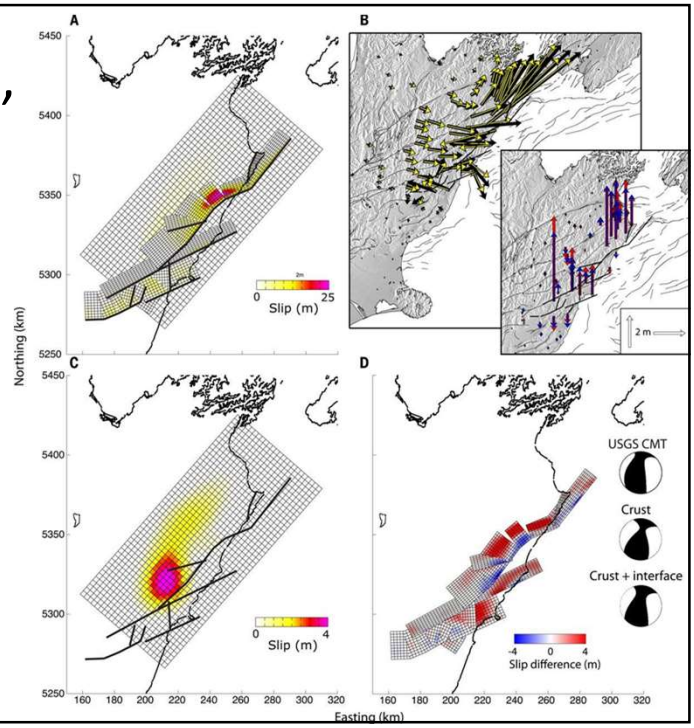
2016 M 7.8 Kaikōura, New Zealand

Even greater complexity than Landers involving:

- **at least 12 large faults**
- **very different fault orientations**
- **multiple slip directions**



Hamling et al. **(2017)**

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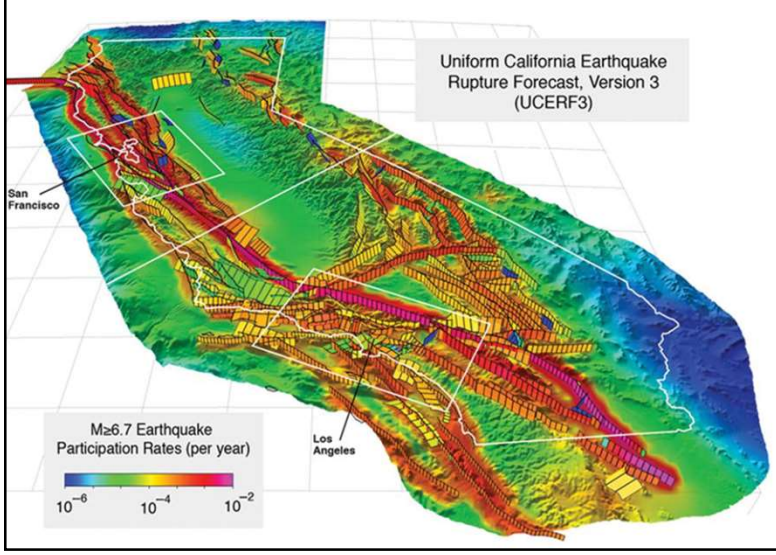
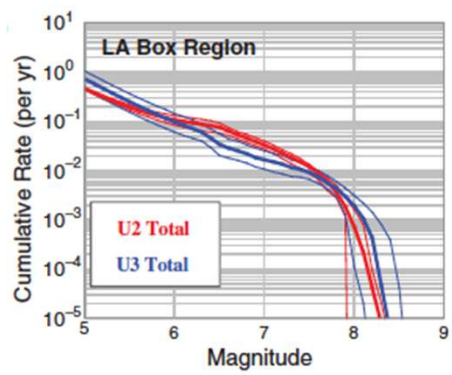
Long-Term Forecasting





Improved modeling of segmentation has had a lasting impact on earthquake rupture forecasting. The unexpected "bulge" at magnitude 6-7 for Los Angeles area earthquake forecasts disappeared once multi-fault ruptures were considered.

Field et al. **(2017)**

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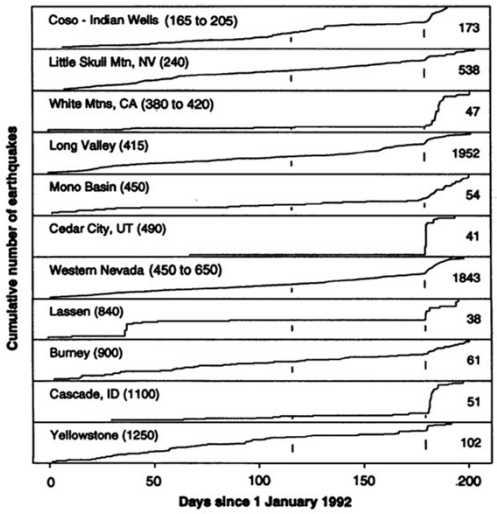
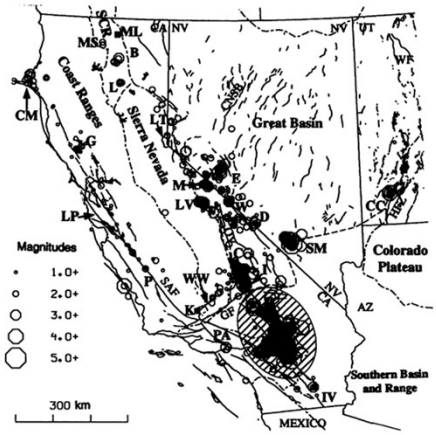
Remote Triggering





Hill et al. (1993)

Clear observation of a sudden increase in seismicity or "aftershocks" observed as far away as Yellowstone.

This overturned the notion that earthquake interaction is localized to the region that hosted the rupture.

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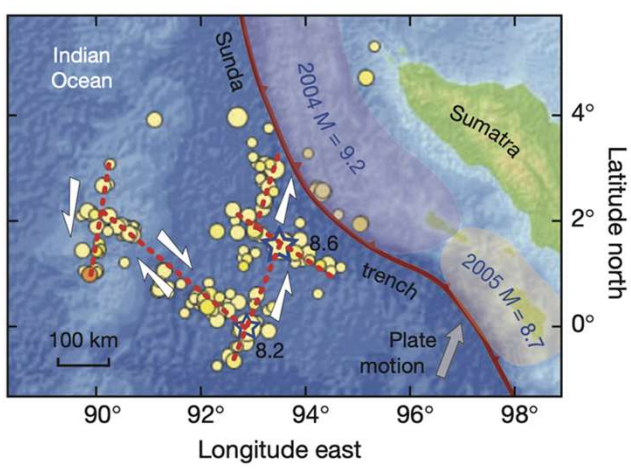
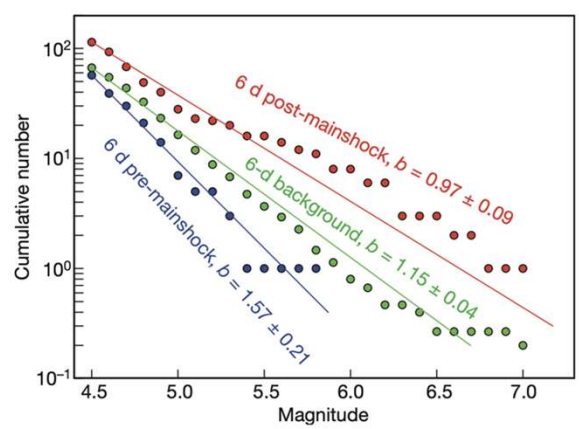
Remote Triggering





Pollitz et al. (2012)

Following the 2012 Off-Sumatra earthquake there was a transient increase in moderate earthquakes around the world. Without evidence of remote-triggering from Landers, such effects would likely be discounted.

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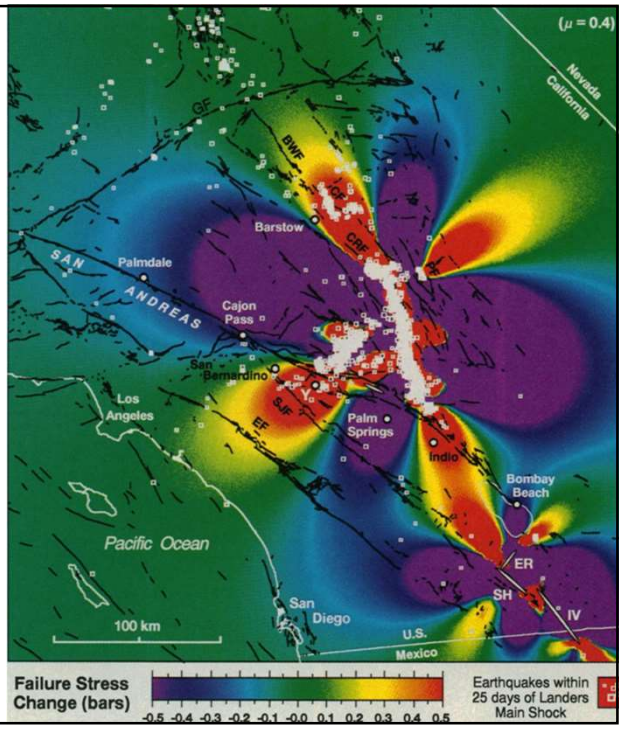
Stress Triggering

The Landers earthquake was not on the San Andreas Fault, but it was close enough to impart significant stress on the San Andreas. In this model of that effect:

Areas in the warm colors (yellow-red) were moved closer to failure.

Areas in cool colors (blue to purple) were moved farther from failure.



***Stein et al.* (1993)**

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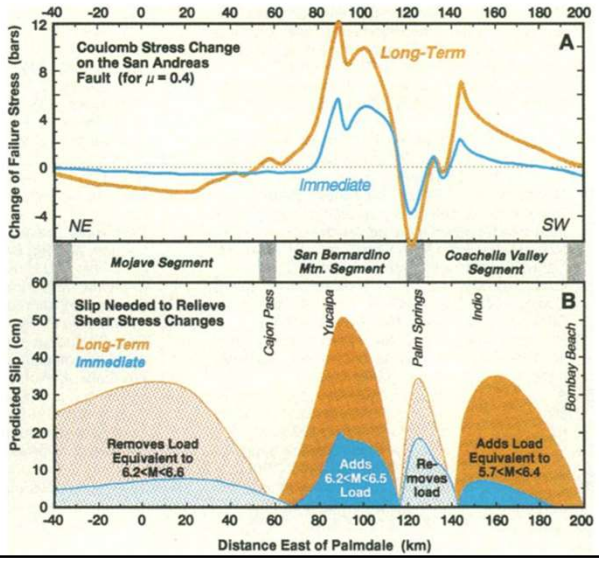
Stress Triggering



The Landers earthquake was not on the San Andreas Fault, but it was close enough to impart enough stress to bring parts of the San Andreas in the Coachella Valley and San Bernardino closer to failure by one or two decades.

Fortunately, no San Andreas Fault earthquake was triggered, but such calculations are now commonly done to quantify changes in hazard due to earthquake interaction. This study raises an interesting question – how do we have confidence in such forecasts?

***Stein et al.* (1993)**

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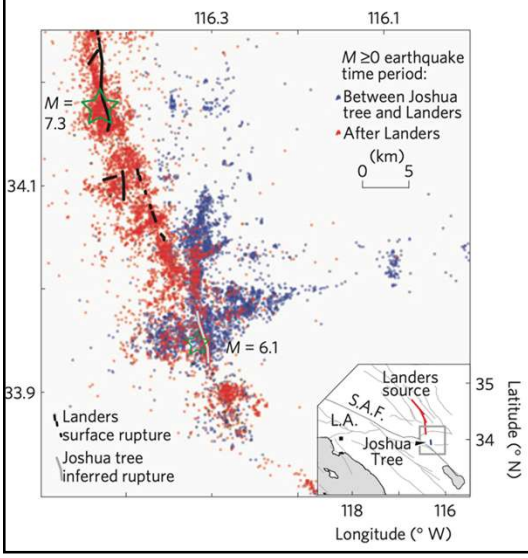
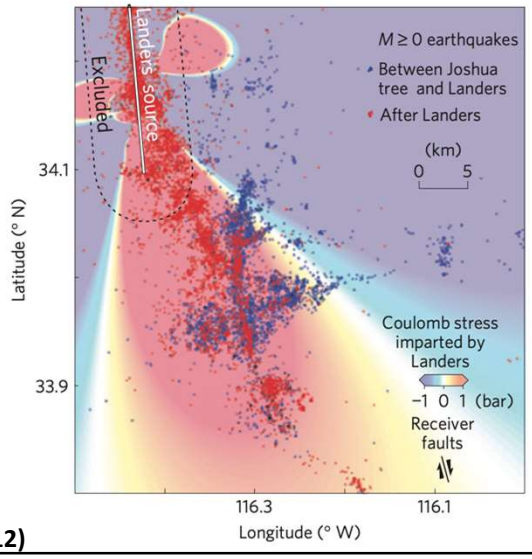
Stress Triggering/Shadowing





***Toda et al.* (2012)**

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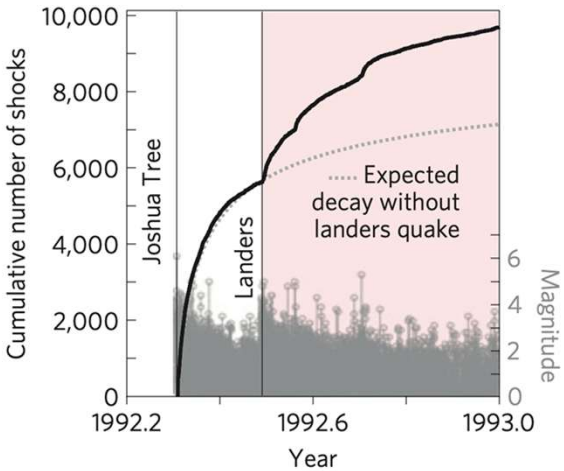
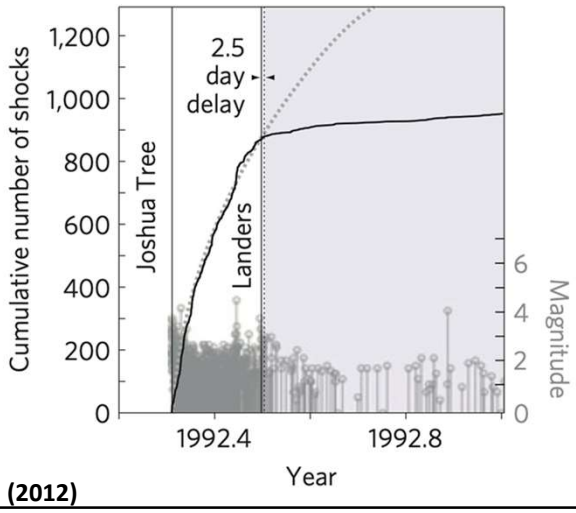
Stress Triggering



Stress Shadowing



***Toda et al.* (2012)**

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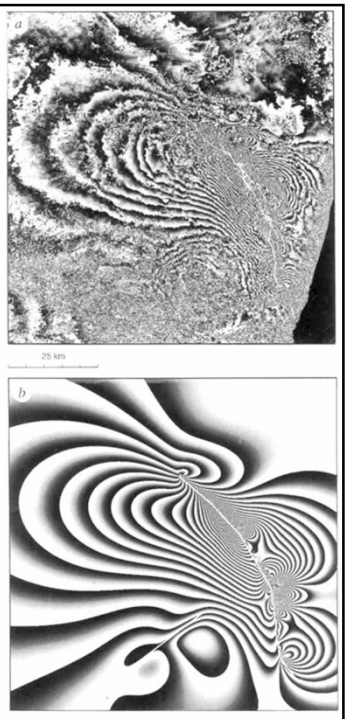
Satellite Interferometry

The Landers earthquake saw the first use of satellite interferometry to study an earthquake. The upper panel shows the fringe pattern due to deformation from the earthquake and the lower panel shows a theoretical prediction of that pattern.

Satellite Interferometry (InSAR) is now used routinely to study large earthquakes, slow deformation between earthquakes, as well as volcanoes, glaciers, groundwater withdrawal…

***Massonnet et al.* (1993)**



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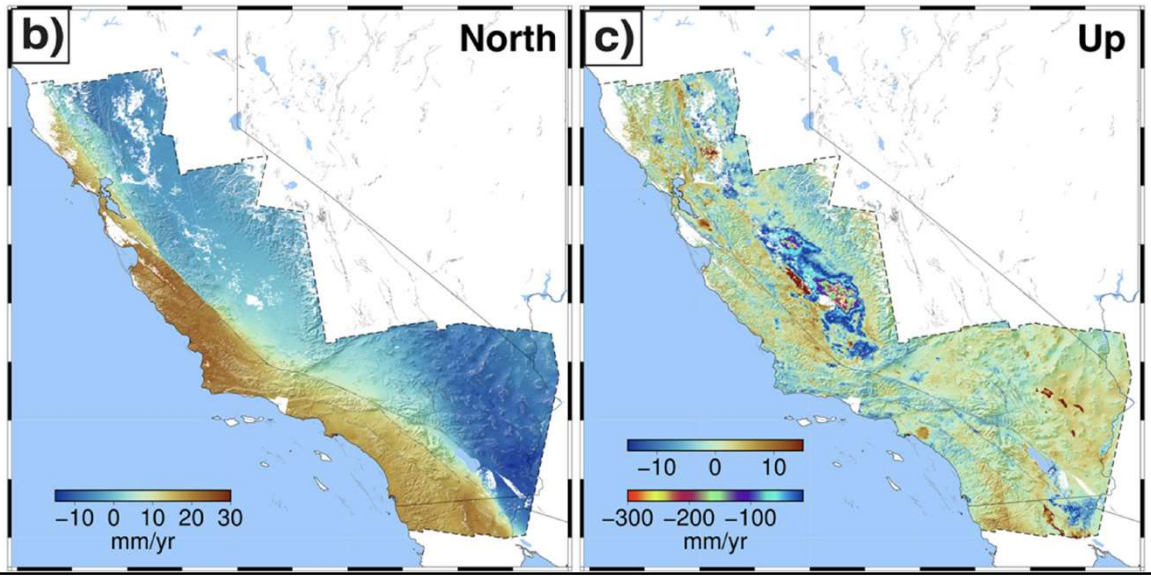
InSAR Deformation Measurements

***Xu et al.* (2021)**



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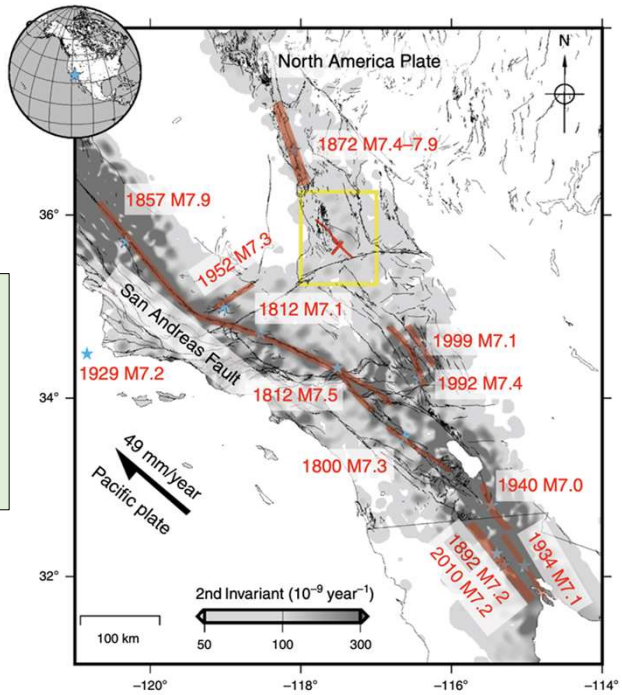
Eastern California Shear Zone

The 2019 Ridgecrest earthquake sequence, which included M 6.5 and M 7.1 events, is the latest in a series of earthquakes to occur off the main San Andreas Fault plate boundary fault system. Some occurred before Landers, while others like Hector Mine and Ridgecrest occurred after.



Chu et al. (1993)

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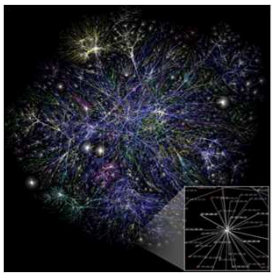
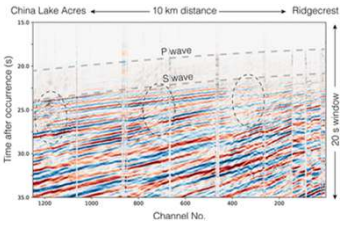
Other developments

Internet Connectivity

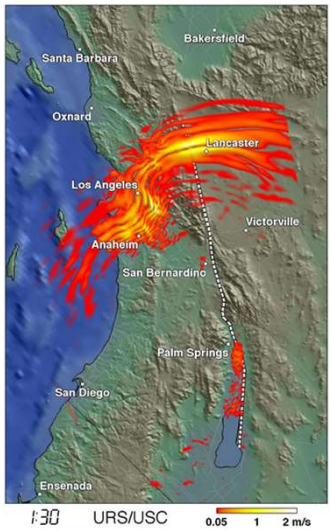


Cheap Sensors

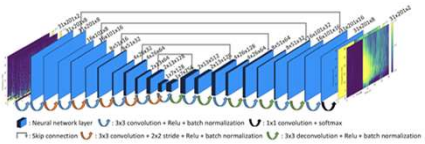
Fiber-Optic Seismology



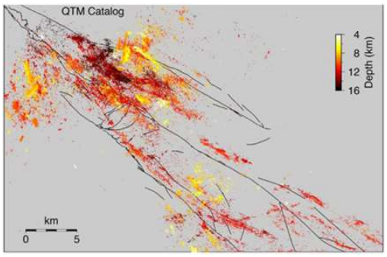
HPC Simulations of Scenario Earthquakes



Machine Learning



Deep Earthquake Catalogs



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