USGS
science for a changing world

# US Geological Survey Investments in GPS

**PNT Advisory Board**

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# Key Applications of GPS in USGS

- Coastal and marine studies
- Geologic mapping & research
- Hydrologic mapping & research
- Watershed, water use, & hydrologic applications
- Natural resource inventory & management
- Survey control
- Land use & land cover
- Geologic hazard assessment & monitoring

# USGS hazard roles and responsibilities

- Delegated federal responsibility to provide notifications and warnings for earthquakes, volcanic eruptions, and landslides.
- Seismic networks support NOAA's tsunami warnings.
- Streamgages and storm surge monitors support NOAA's flood and severe weather (including hurricane) warnings.
- Geomagnetic observatories support NOAA and AFWA geomagnetic storm forecasts.
- USGS has key role in tracking zoonotic diseases.
- Geospatial information supports response operations for wildfire and many other disasters.





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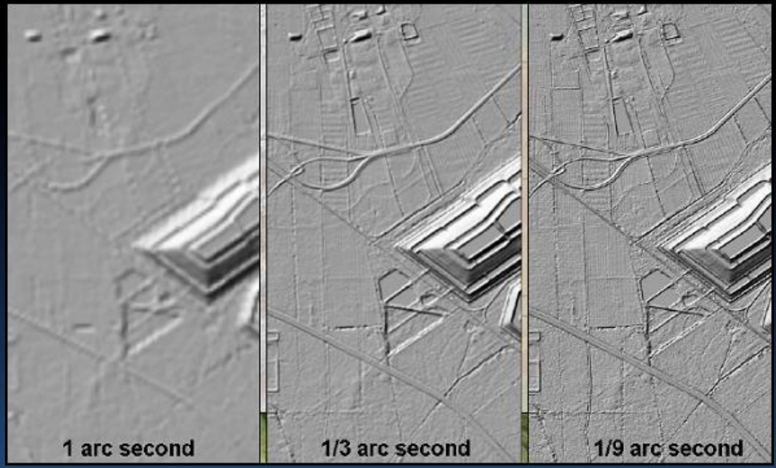
# GPS used for Streamgaging

- 9,000 USGS streamgages and water-quality monitoring sites use GPS timing for satellite communications

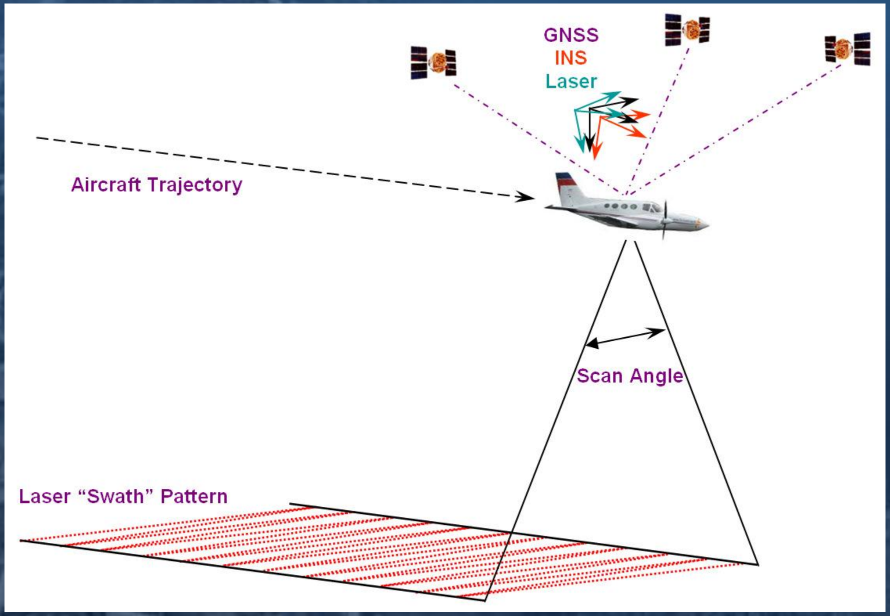
# GPS used for high-accuracy base geospatial data products

GPS

GPS provides precise positions of airborne sensors so that highly accurate base geospatial data products such as high resolution terrain (elevation) data and orthorectified imagery can be produced efficiently.

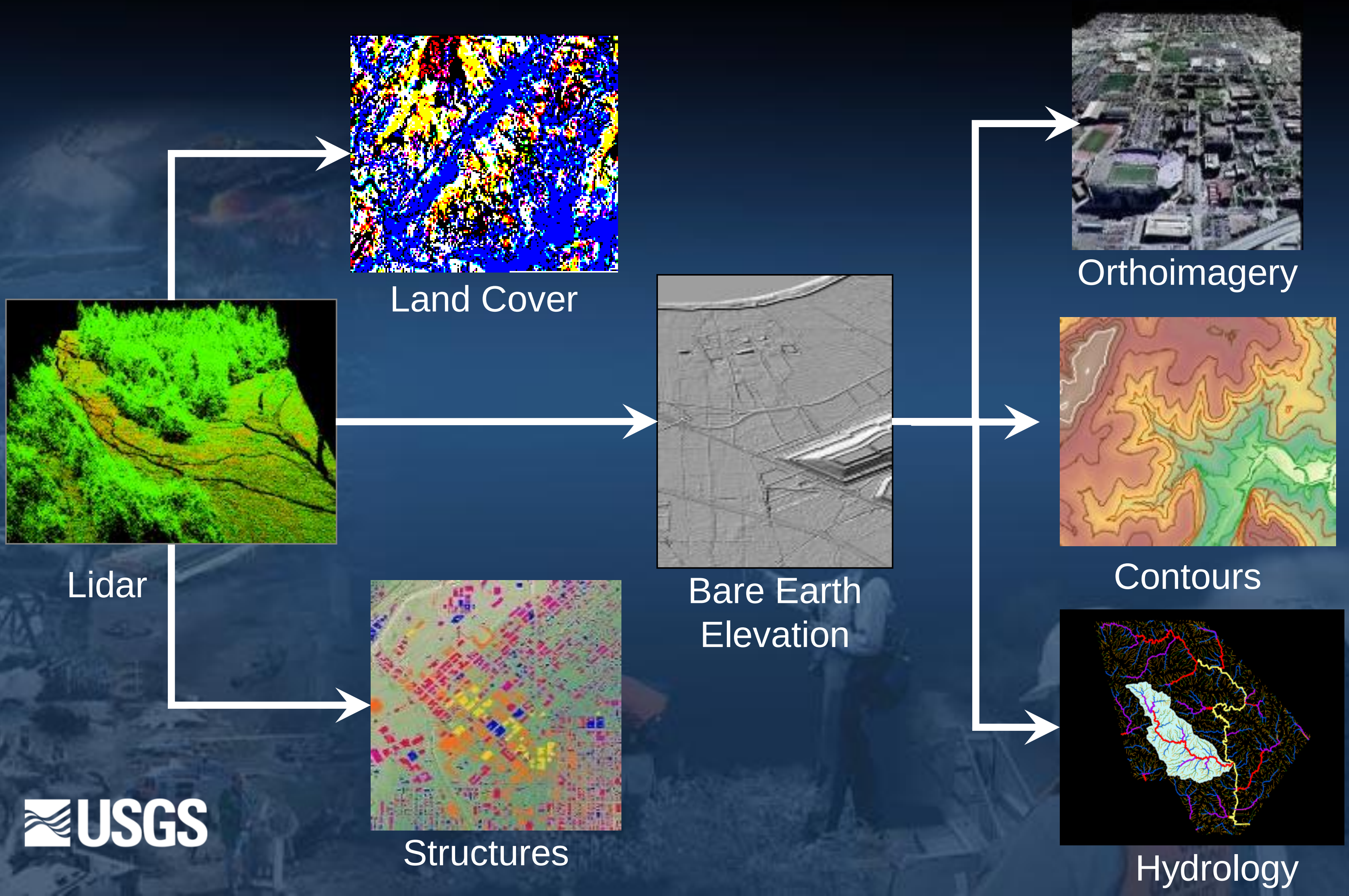



Highly accurate terrain elevation data is replacing older, lower resolution data

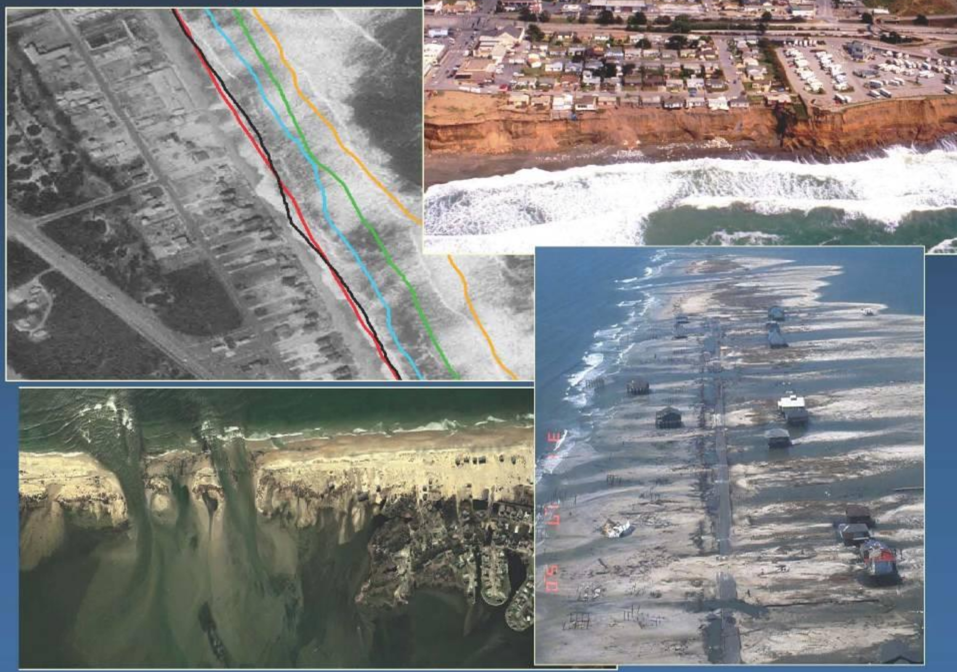



Example of high resolution orthorectified imagery acquired in partnership with other Fed, state, and local agencies

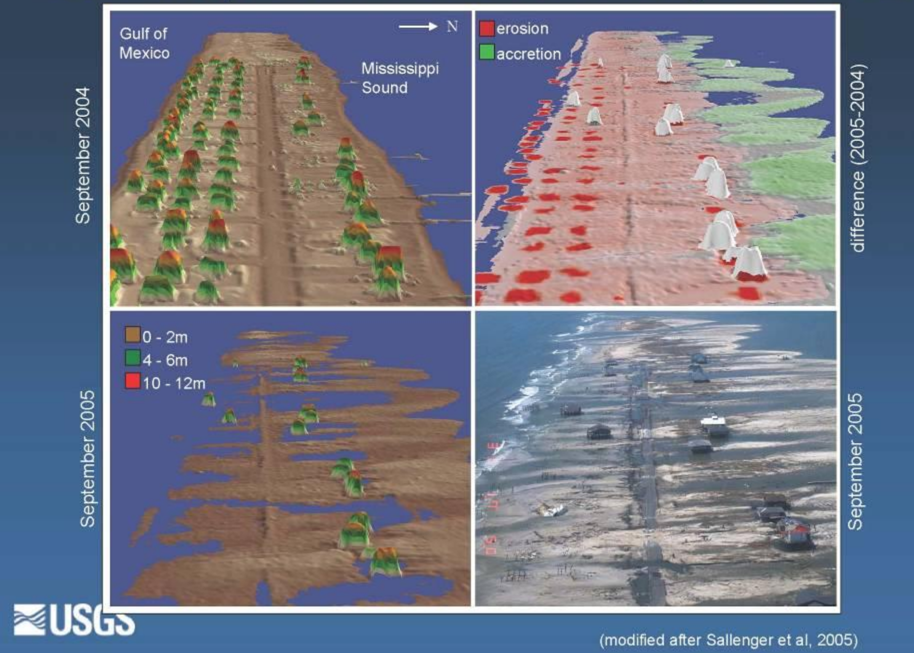
# Accurate Lidar mapping is highly relevant to several data layers of The National Map

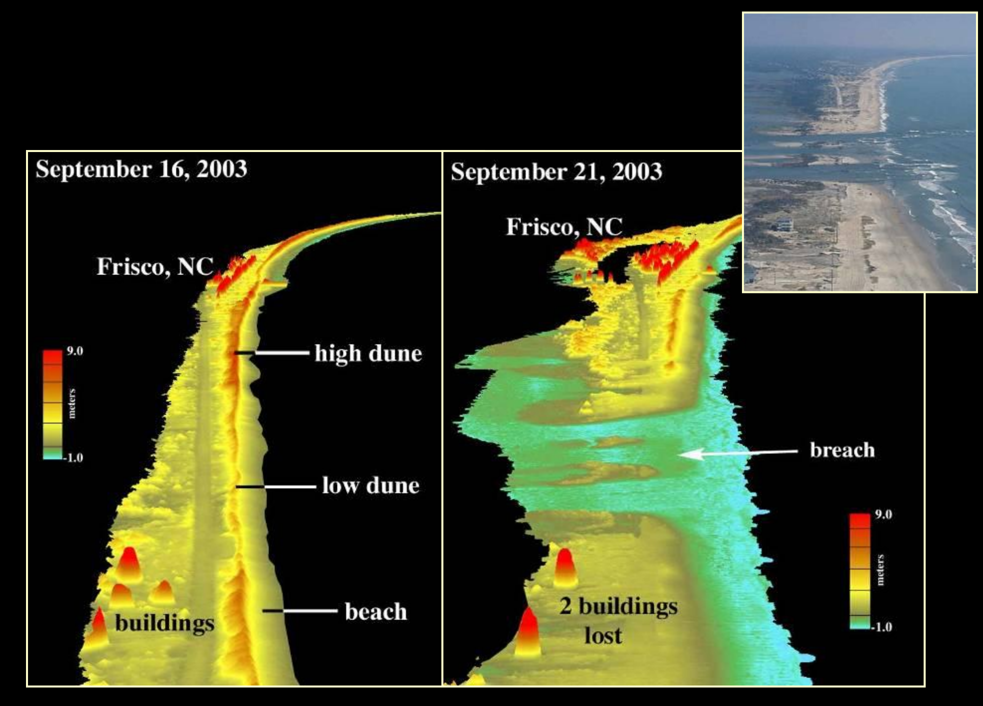


## Coastal Change Hazards

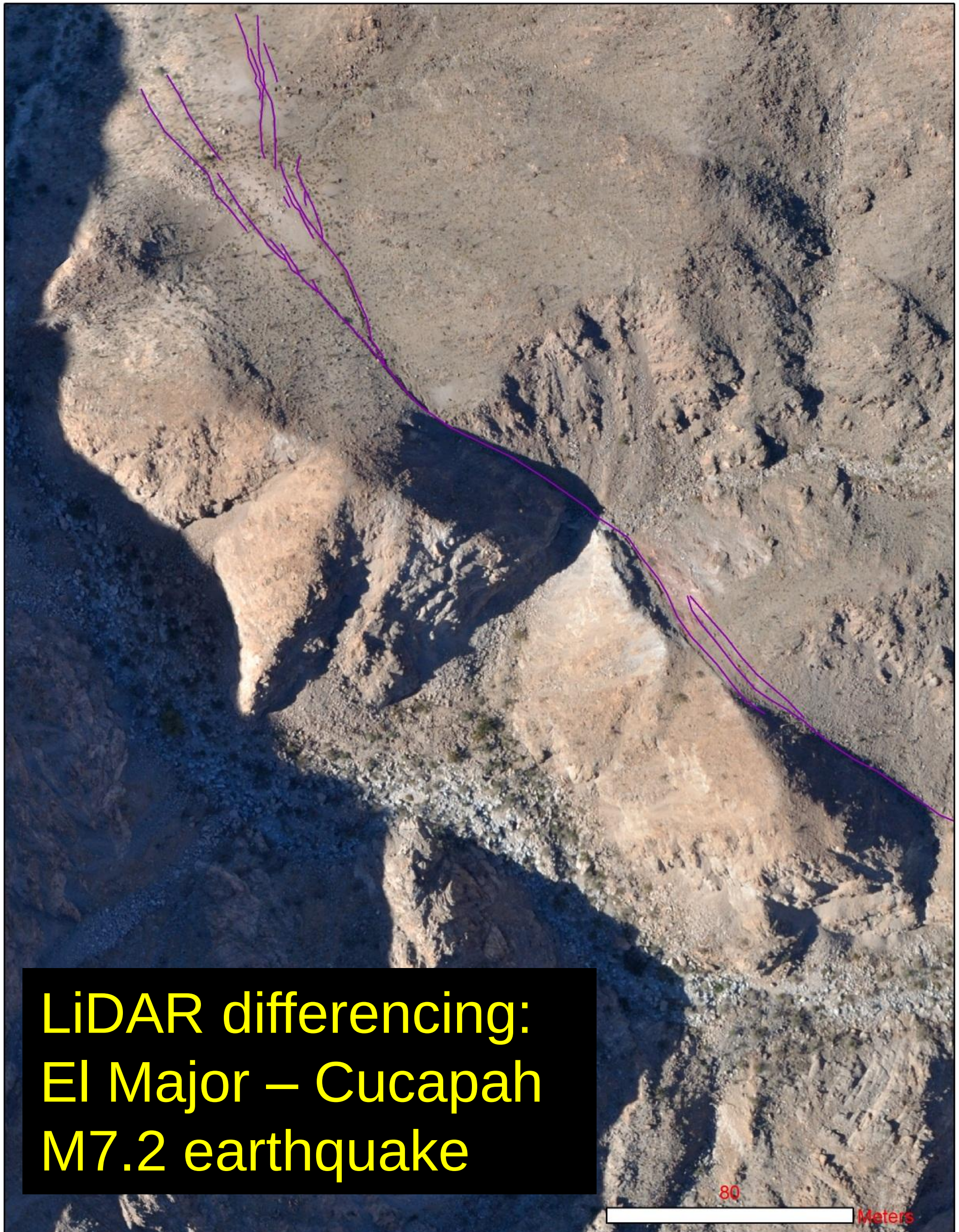


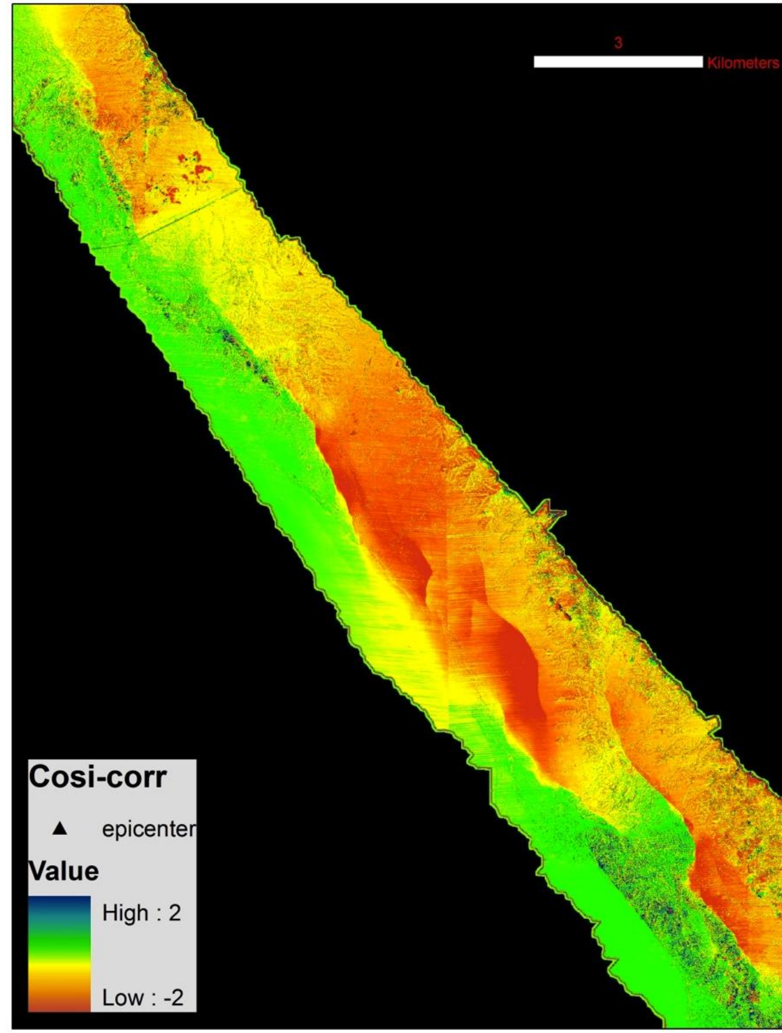
## Coastal Response to Hurricane Katrina - Dauphin Island, AL




# GPS Dependent Airborne Lidar Mapping Enables Understanding of Coastal Change Hazards

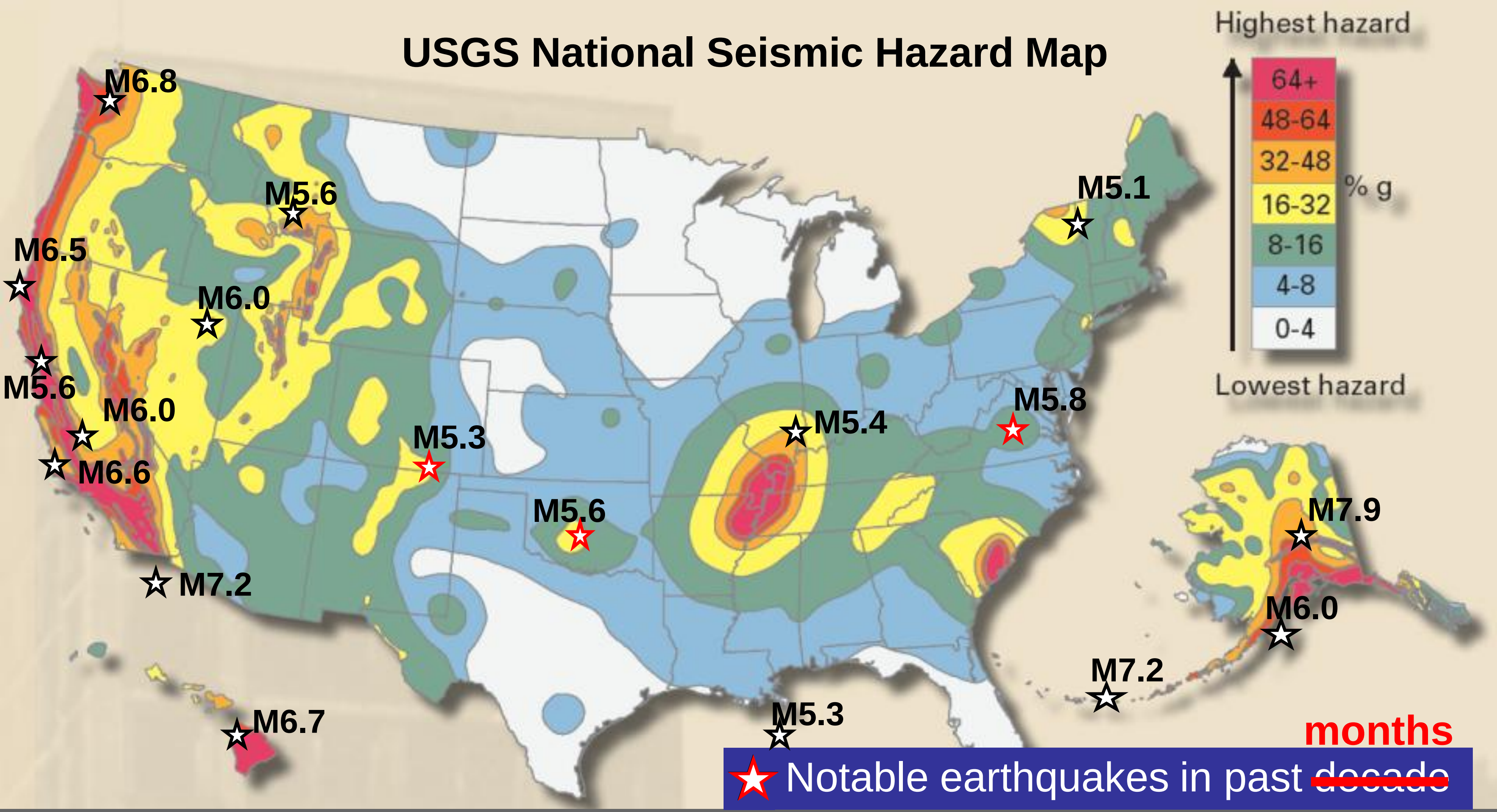


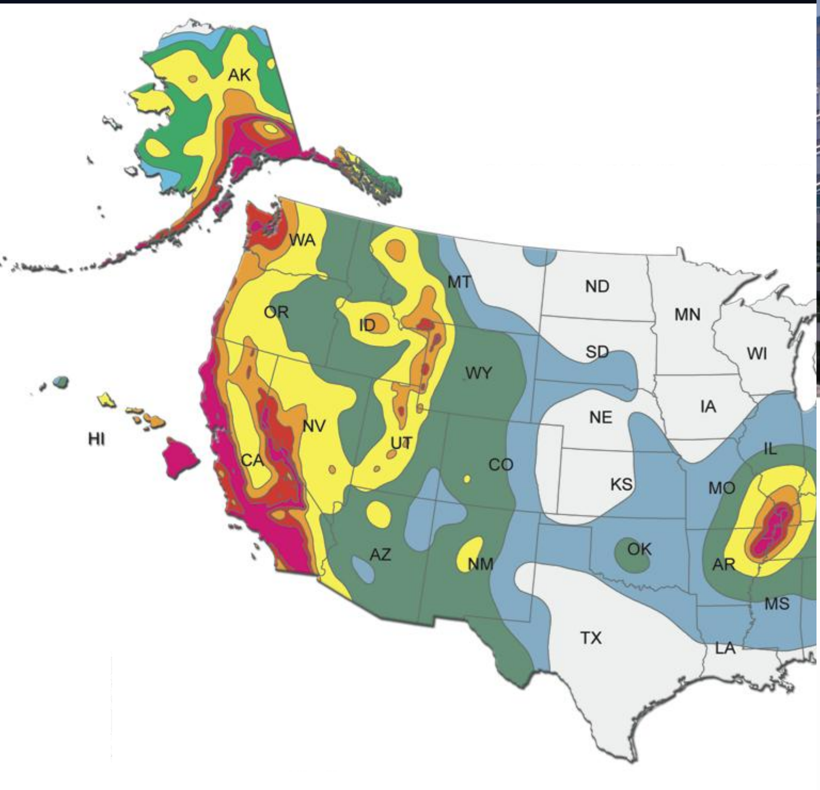

GPS enables ultra-high-precision geo-ref for fault mapping using repeat-pass imagery

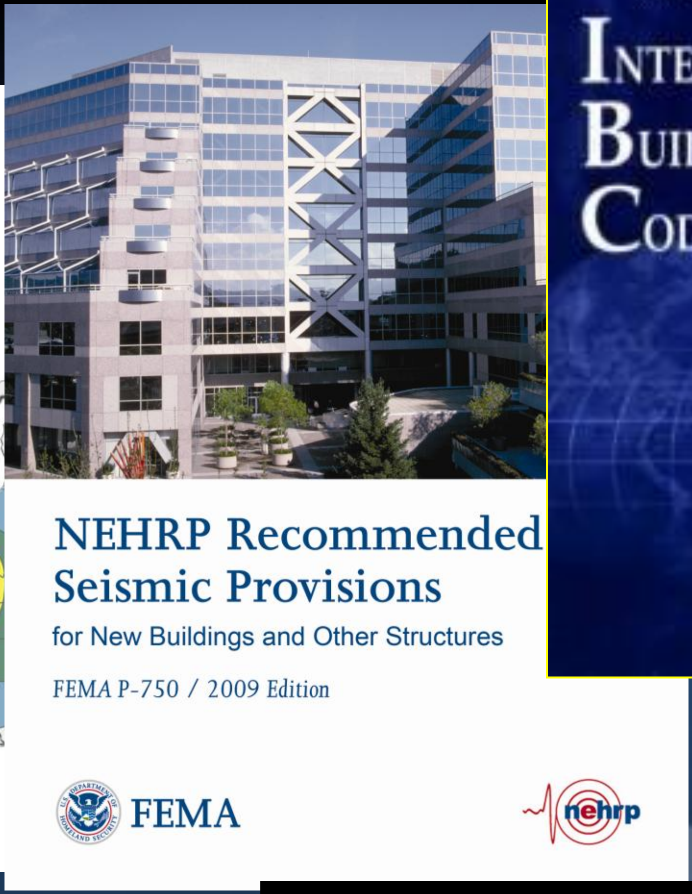
- LiDAR
- 3D stereo

# Earthquakes are a national hazard



# The heart of NEHRP: Translating USGS national hazard maps into model building codes





**Seismic element of NEHRP Provisions and Int'l Building Code based on the USGS national seismic hazard map**

USGS nehrp

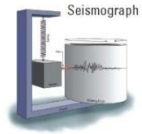
# Building a seismic hazard assessment

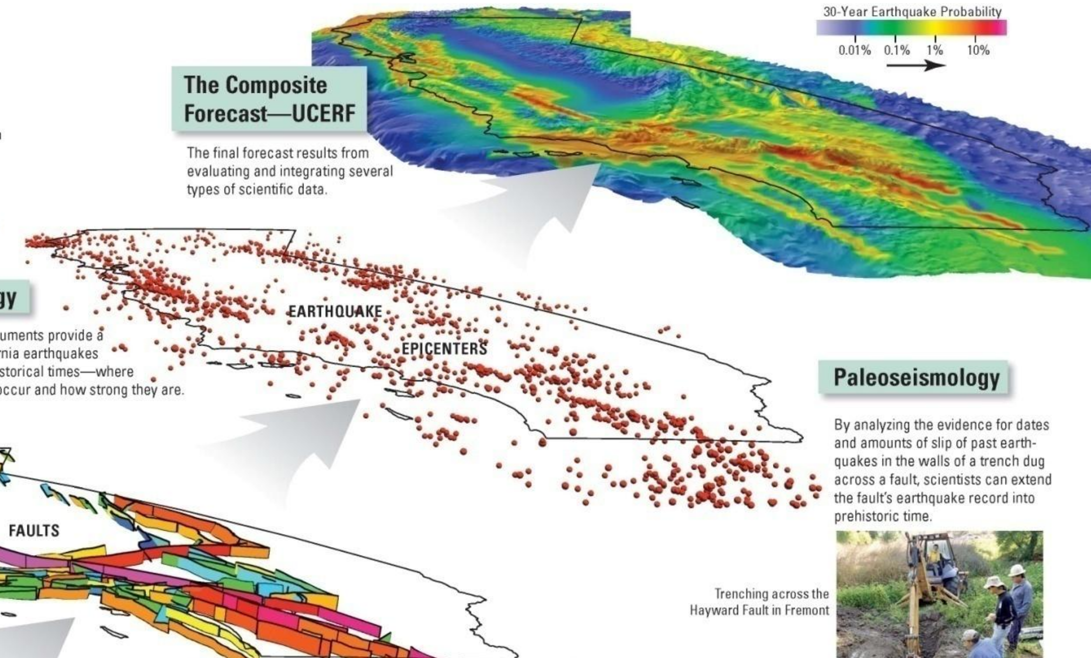
## How Did Scientists Make This Forecast?

**California sits on the boundary between two of the Earth's major tectonic plates—the Pacific and North American Plates—which move inexorably past each other at a rate of about 2 inches per year. Much of this motion is accommodated from time to time by sudden slip on faults, producing earthquakes. Although the San Andreas Fault is the main locus of slip, hundreds, if not thousands, of other faults splay out from the plate boundary, spreading the threat of large earthquake ruptures through most of the State.**

The new Uniform California Earthquake Rupture Forecast (UCERF) combines information from **geodesy** (precise data on the slow relative movement of the Earth's tectonic plates), **geology** (mapped locations of faults and documented offsets on them), **seismology** (occurrence patterns of past earthquakes), and **paleoseismology** (data from trenches across faults documenting the dates and offsets of past earthquakes on them). The first three kinds of data are shown here as layers in the diagram. All four kinds of data are combined mathematically to produce the final probability values for future ruptures in the California area, in regions of the State, and on individual faults.

Building on several previous studies and decades of data collection, UCERF was developed by a multidisciplinary group of scientists and engineers, known as the 2007 Working Group on California Earthquake Probabilities. Advice and comment was sought regularly from the broader community of earthquake scientists and engineers through open meetings and workshops. Where experts disagreed on aspects of the forecast, alternative options were accounted for in calculations to reflect these uncertainties. The final forecast is a sophisticated integration of scientific fact and expert opinion.




### The Composite Forecast—UCERF

The final forecast results from evaluating and integrating several types of scientific data.

### Seismology

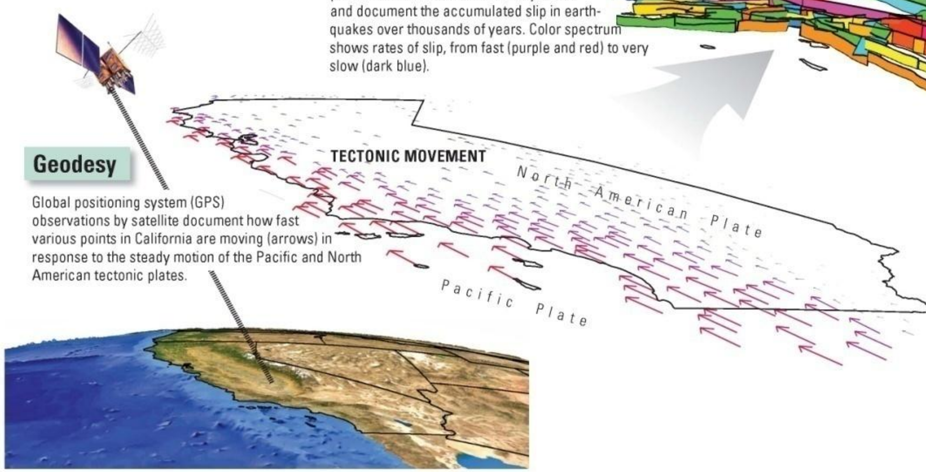
Monitoring instruments provide a record of California earthquakes during recent historical times—where and when they occur and how strong they are.

### Geology

Geologic field mapping and aerial photos trace out California's many faults and document the accumulated slip in earthquakes over thousands of years. Color spectrum shows rates of slip, from fast (purple and red) to very slow (dark blue).

### Geodesy

Global positioning system (GPS) observations by satellite document how fast various points in California are moving (arrows) in response to the steady motion of the Pacific and North American tectonic plates.




### Paleoseismology

By analyzing the evidence for dates and amounts of slip of past earthquakes in the walls of a trench dug across a fault, scientists can extend the fault's earthquake record into prehistoric time.

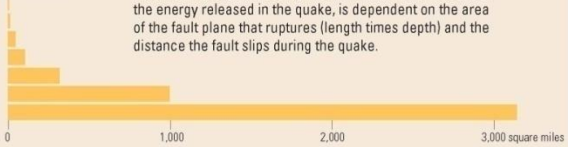
Trenching across the Hayward Fault in Fremont

The San Andreas Fault passes through the Carrizo Plain

**Earthquake Magnitudes and the Areas of Fault Rupture**

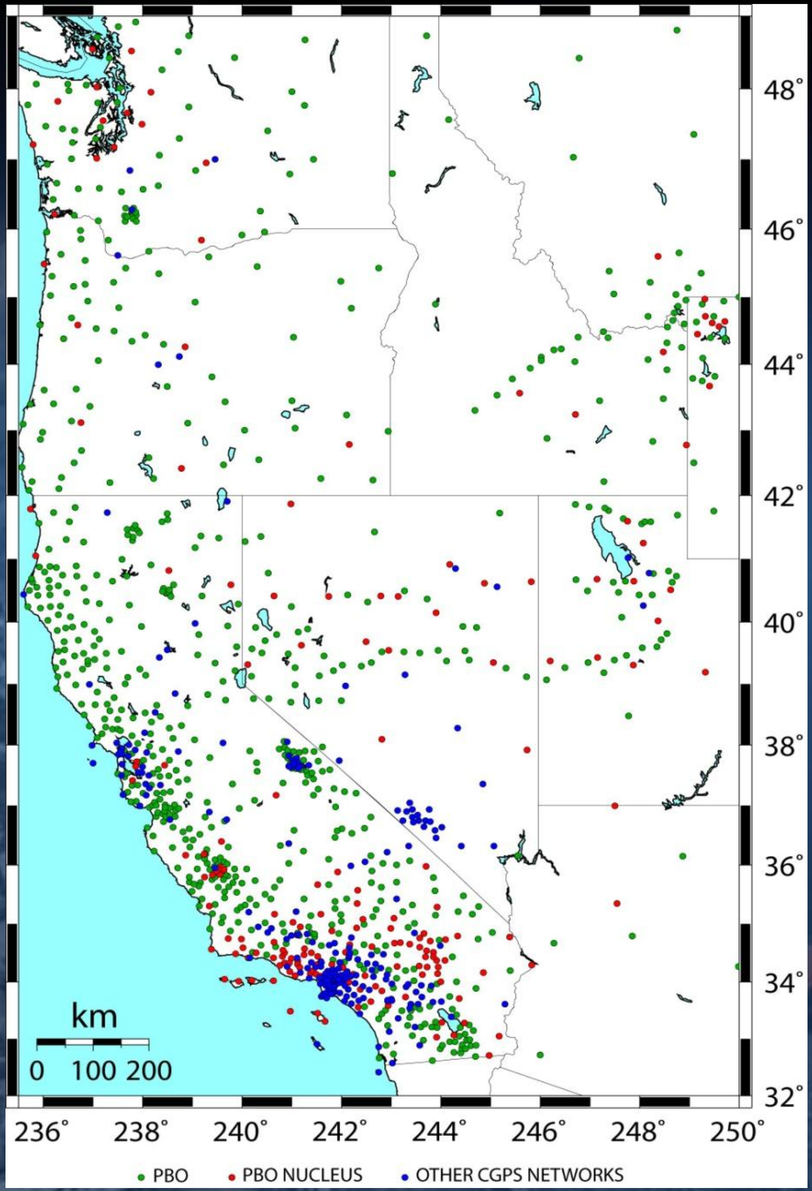
The magnitude of an earthquake (M), which is a measure of the energy released in the quake, is dependent on the area of the fault plane that ruptures (length times depth) and the distance the fault slips during the quake.

| | Fault Plane Ruptured | | | |
|---|---|---|---|---|
| M | Length (miles) | Depth (miles) | Average slip (feet) | Area (square miles) |
| 5.0 | 1.8 | 1.8 | 0.5 | |
| 5.5 | 3.1 | 3.1 | 0.8 | |
| 6.0 | 5.6 | 5.6 | 1.5 | |
| 6.5 | 13 | 7.5 | 2.7 | |
| 7.0 | 42 | 7.5 | 4.8 | |
| 7.5 | 133 | 7.5 | 8.5 | |
| 8.0 | 420 | 7.5 | 15 | |

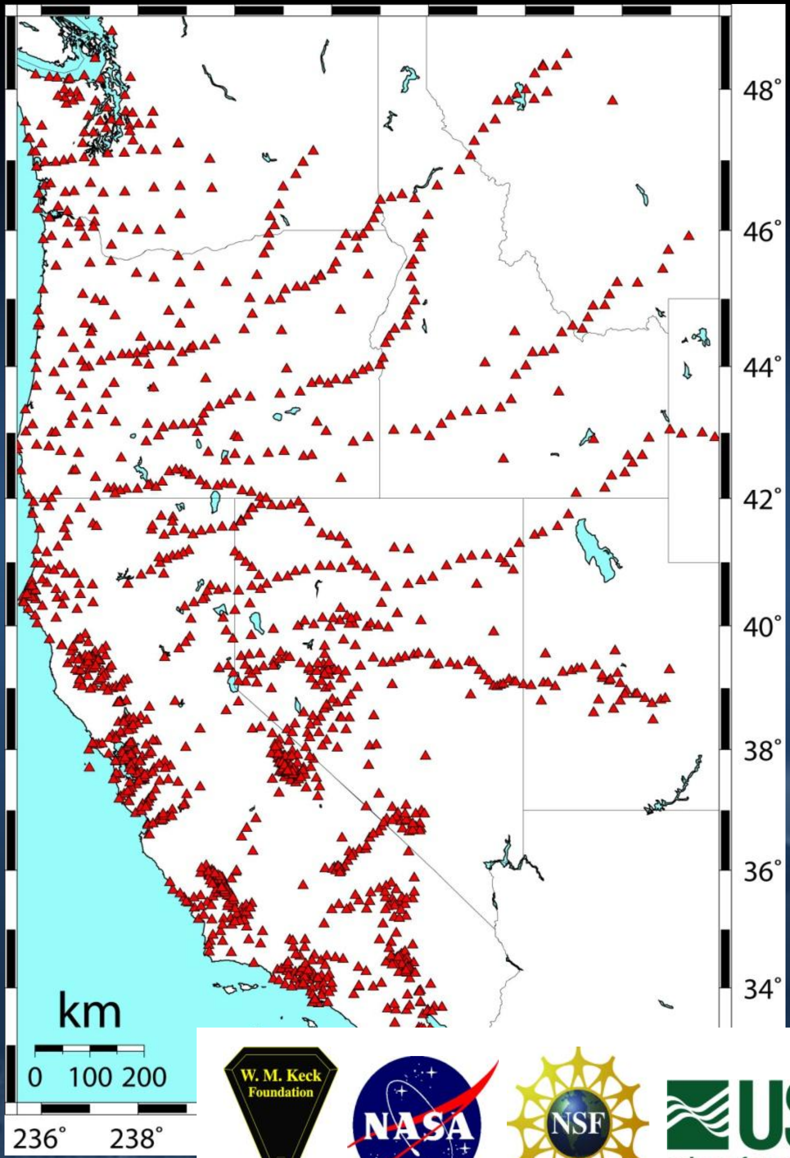


# Continuous and campaign GPS arrays

Continuously Operating GPS Stations




Campaign Survey GPS Points

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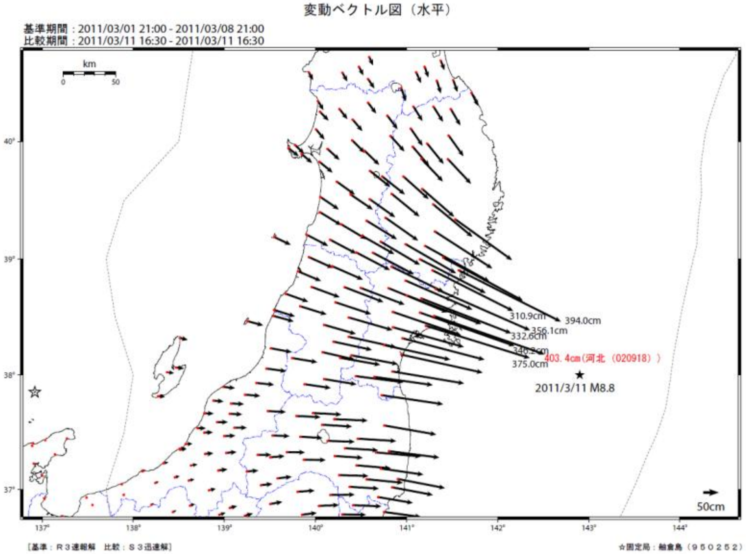
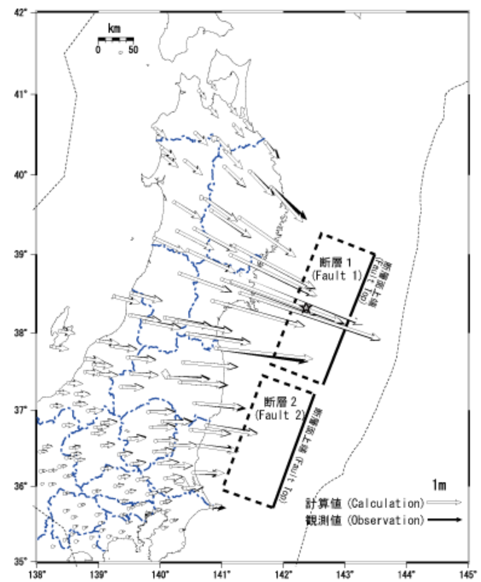
**During** 2011 Japan earthquake:

Initial GPS results from GSI showed 2.6 meters shift; later results gave maximum GPS offset of 4.034 m (that’s 13 feet)

Data were openly available and other groups quickly confirmed these results and made movies of the displacements to help visualize the information




星印はUSGSの震央（142.369°，38.322°）
A Star indicates an epicenter released from USGS (142.369°, 38.322°)

矩形断層2枚での推定結果
Two rectangular faults with uniform slip are assumed.

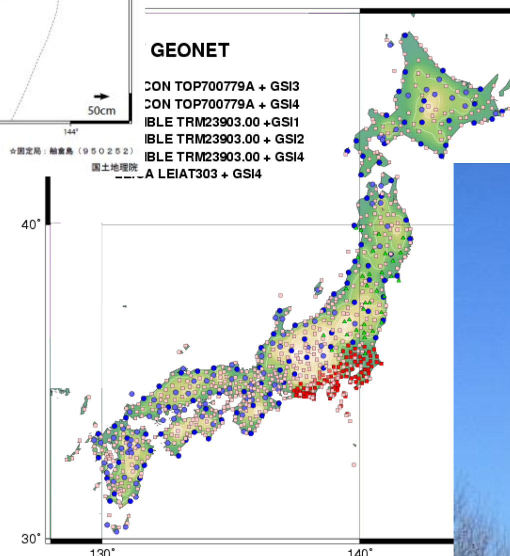
西側に傾き下がる逆断層．モーメントマグニチュードは北側（断層1）が8.7，南側（断層2）が8.2．2つ合わせて8.8（暫定）．
West-dipping reverse fault. Total moment magnitude: Mw8.8. (Northern segment: Mw=8.7, Southern segment: Mw=8.2)

断層の長さは南北に約200kmの断層1と約180kmの断層2で合計約380km．総延長はおよそ400km．
Total major rupture length: ~400 km (Fault Length: Northern segment ~200 km / Southern segment ~180 km)

| | 緯度 Lat | 経度 Lon | 上端深さ Depth (Fault Top) km | 長さ Length km | 幅 Width km | 走向 Strike | 傾斜角 Dip | すべり角 Rake | すべり量 Slip m | Mw |
|---|---|---|---|---|---|---|---|---|---|---|
| 断層1 | 39.00° | 143.49° | 10.0 | 199 | 85 | 202° | 18° | 97° | 27.7 | 8.7 |
| 断層2 | 37.21° | 142.51° | 10.1 | 176 | 82 | 201° | 15° | 81° | 5.9 | 8.2 |

国土地理院資料
Geospatial Information Authority of Japan

Since 1990, US advised Japan on construction of continuously-operating GPS stations (like ones we built in Southern California). They built a network of over 1000 GPS stations called GEONET.




**Post**-seismic:

re-adjustments will go on for years, GPS is the best way to examine it

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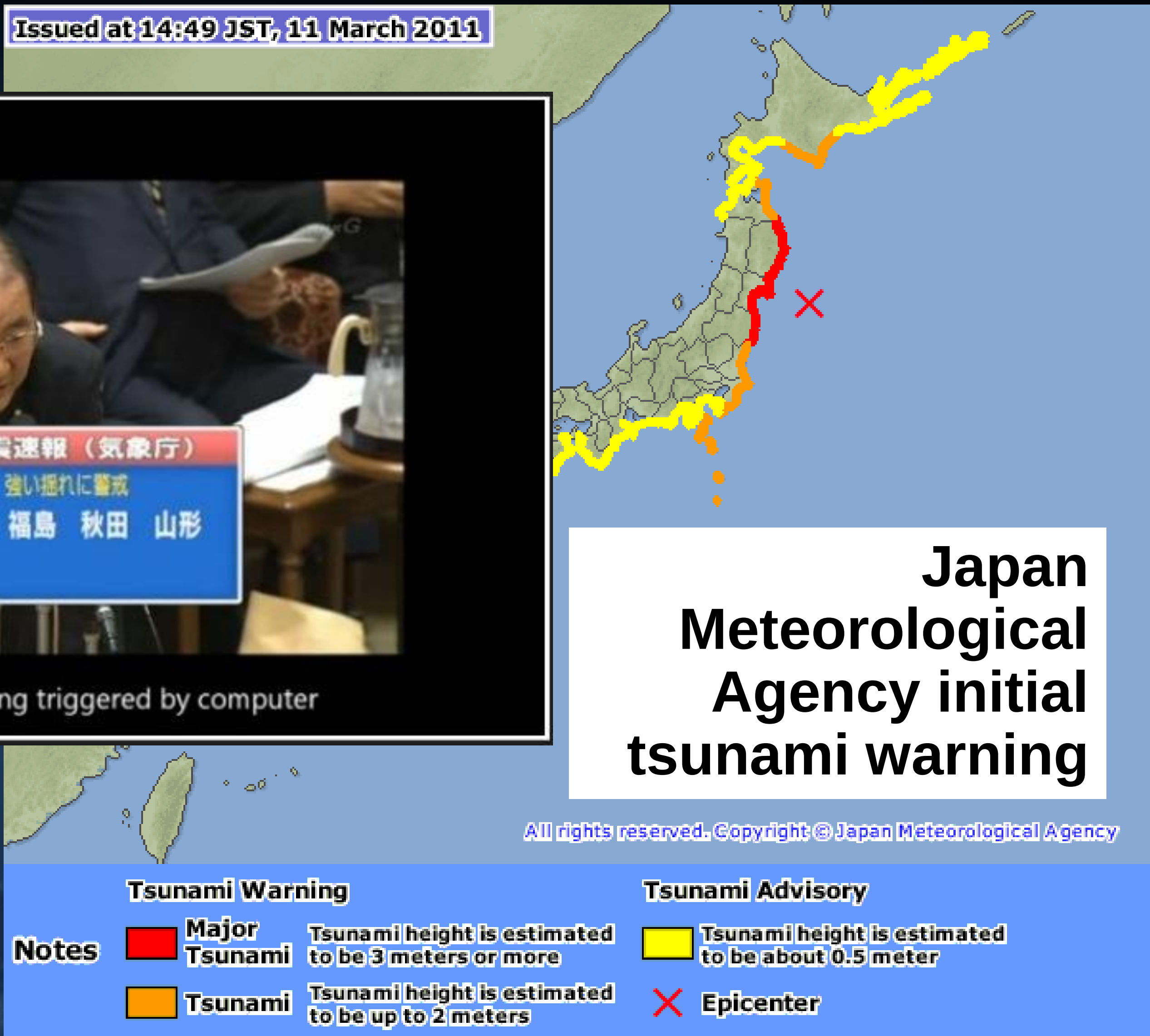
# Japanese early warning systems


**Japan Meteorological Agency initial tsunami warning**

# San Andreas Fault lifeline crossings


GPS & accelerometer arrays are being explored as part of a fully operational earthquake early warning system

# GPS uses by USGS Volcano Hazards Program

- Key component of volcano monitoring for flank movements and lava dome growth
- Integral part of National Volcano Early Warning System plan for monitoring modernization and expansion
- Over 300 continuous GPS units are currently in use by USGS volcano observatories (nearly all of these are telemetered precise dual-frequency stations; many are Plate Boundary Observatory stations operated by UNAVCO with NSF funding)

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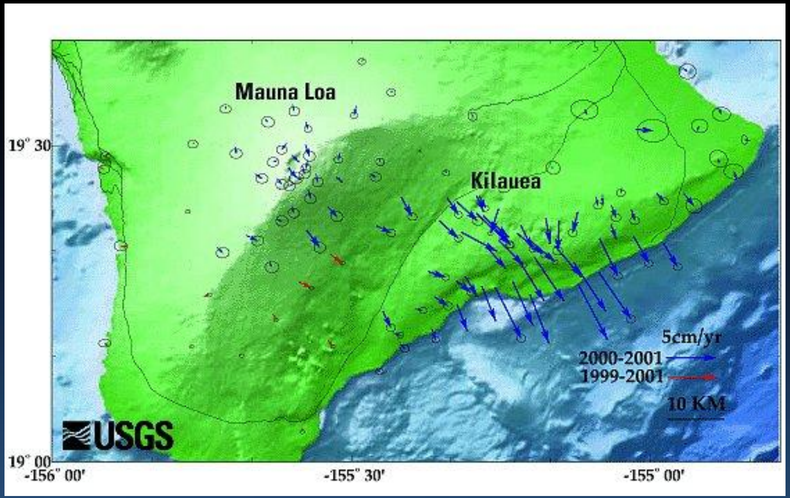
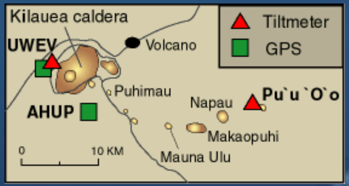
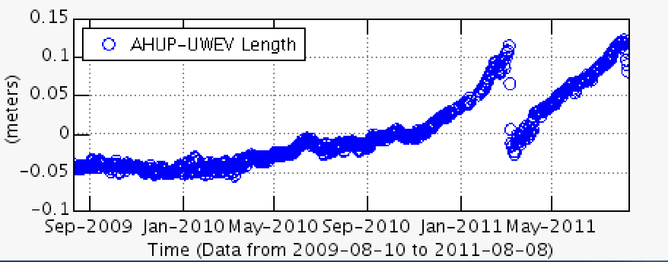
# USGS uses precise GPS for eruption monitoring


Motions of volcanoes' flanks can indicate the arrival of new magma; GPS is used to monitor changes in activity.

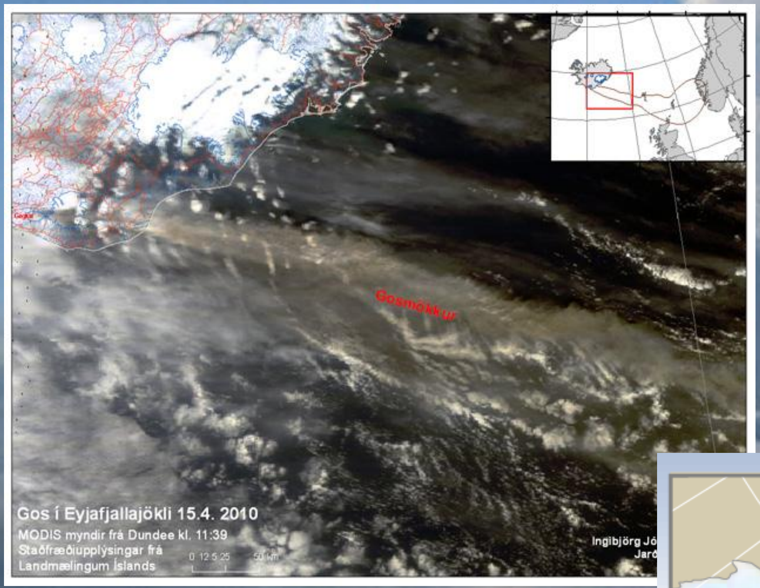


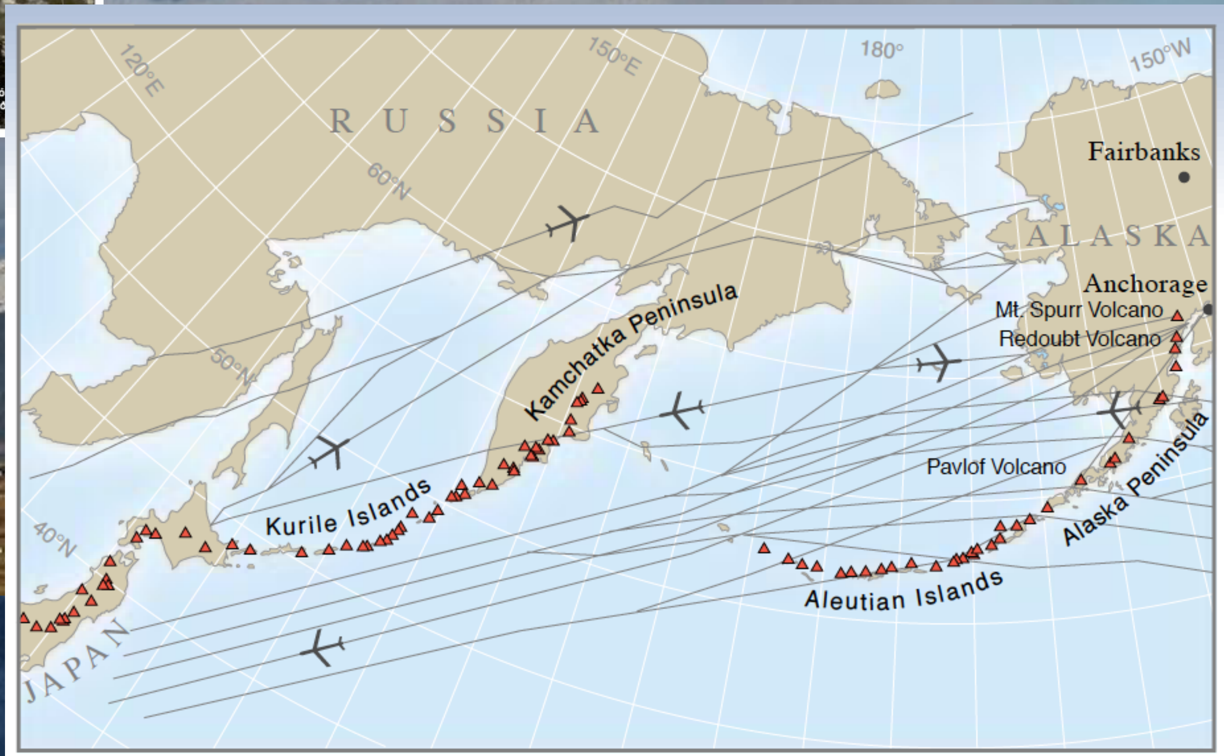





# The eruption of Iceland's Eyjafjallajökull – there is no such thing as a remote volcano



# Impacts on usage if performance degraded

- GPS is an essential enabling technology for mapping and monitoring needed to accomplish USGS science missions in support of hazard warnings, DOI natural resource management, and other societal needs.
- Interference from widely distributed, land-based high-power transmissions could render GPS useless due to thousands of “dead spots”
  - Accuracy would be compromised and reduced.
  - Operations would be disrupted with potentially labor-intensive workarounds if those are even possible.
  - Would raise the cost of operations, and the cost to mitigate would be very expensive.
  - Alternatives could have negative environmental impacts

# Any questions?

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