USGS
science for a changing world

GPS Precision Monitoring of Natural Hazards

USTTI Seminar: Global Positioning System Applications for Disaster Management and Societal Benefits

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U.S. Geological Survey

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Acknowledgements

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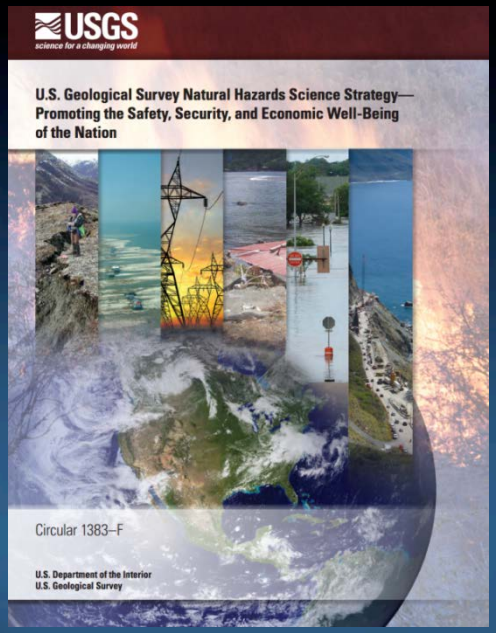
USGS

USGS Natural Hazards Science Strategy

- **Goal 1**: Enhanced observations
- **Goal 2**: Fundamental understanding of hazards and impacts
- **Goal 3**: Improved assessment products and services
- **Goal 4**: Effective situational awareness



USGS

USGS hazard roles and responsibilities

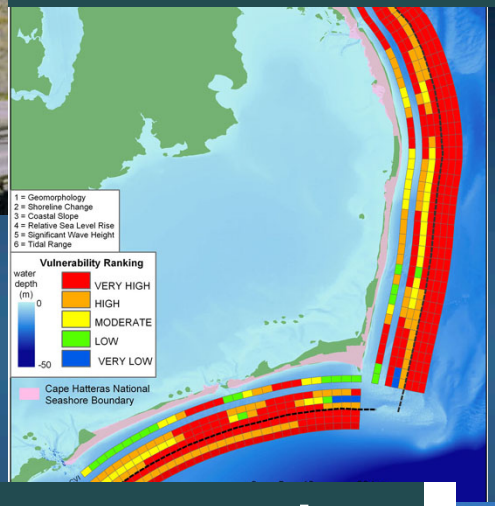
- Responsible for providing assessments and warnings for earthquakes, volcanic eruptions, and landslides
- Seismic networks support NOAA's tsunami warnings
- Streamgages and storm surge monitors support NOAA's flood and severe weather (including hurricane) warnings
- Coastal and marine geologic surveys and research support assessments of earthquake and tsunami hazards, and coastal impacts from storms, hurricanes and sea-level rise
- Geomagnetic observatories support NOAA and AFWA geomagnetic storm forecasts
- USGS has key role in tracking chemical and biological threats, in particular zoonotic diseases
- Geospatial information supports response operations for wildfire and many other disasters

USGS

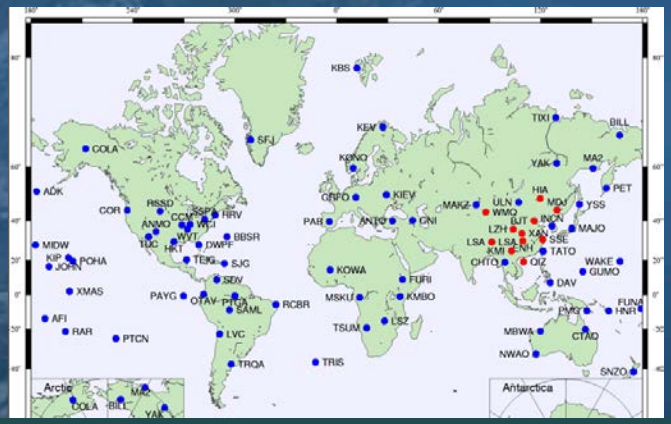
Natural Hazards Mission Area programs

Earthquake Hazards

Coastal & Marine Geology

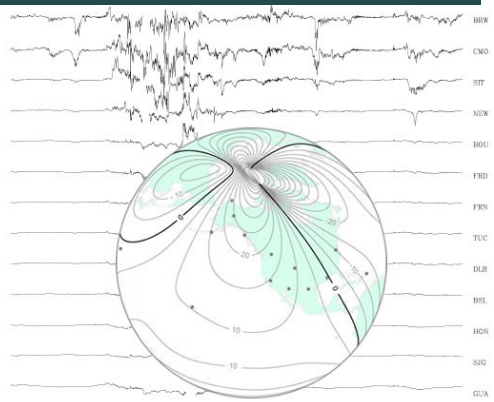


Volcano Hazards



Global Seismographic Network

Geomagnetism

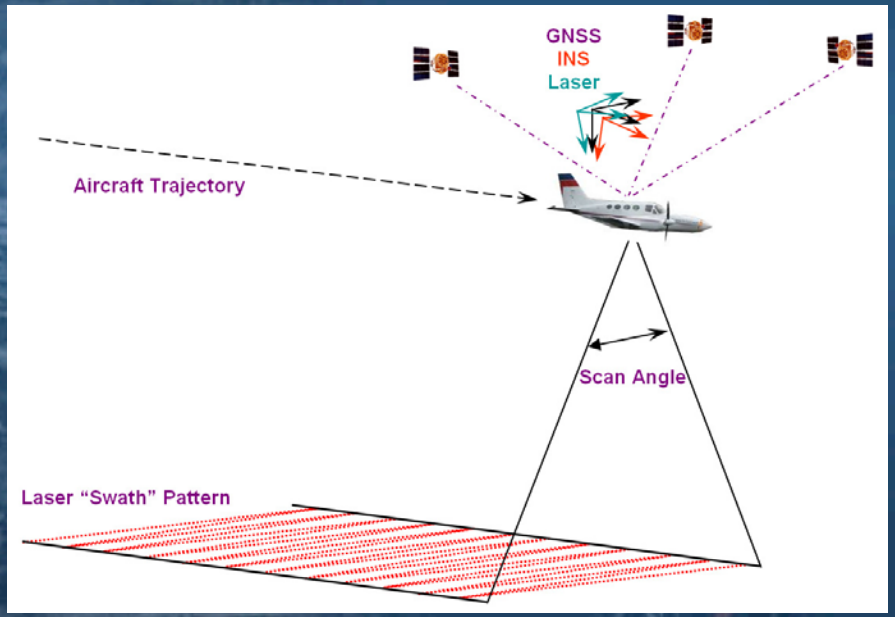


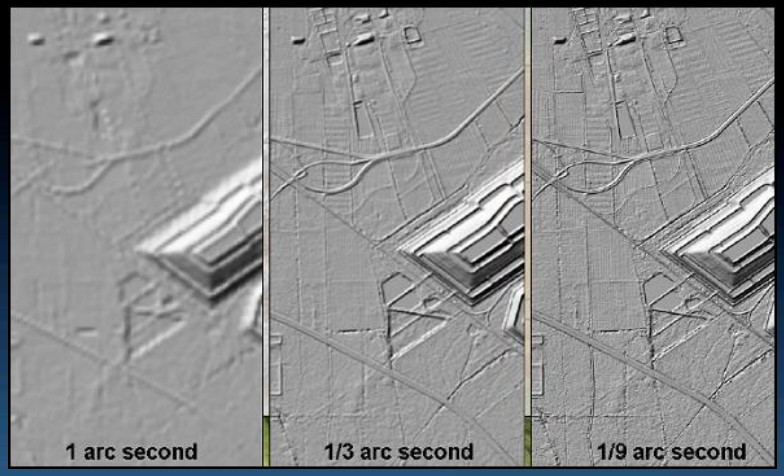
Landslide Hazards

USGS

GPS used for high-accuracy base geospatial data products

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



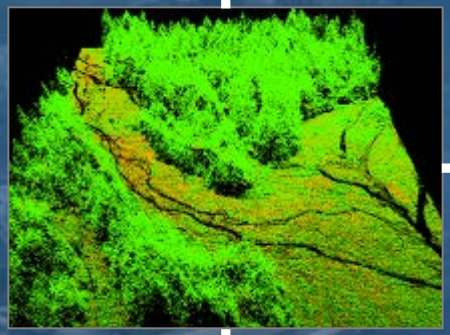


Highly accurate terrain elevation data is replacing older, lower resolution data

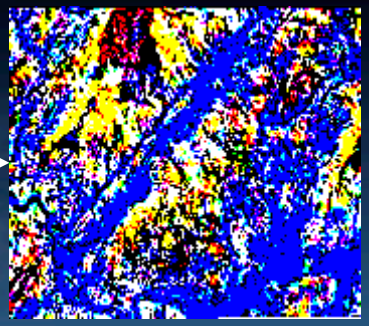
Example of high resolution orthorectified imagery acquired in partnership with other Fed, state, and local agencies

USGS

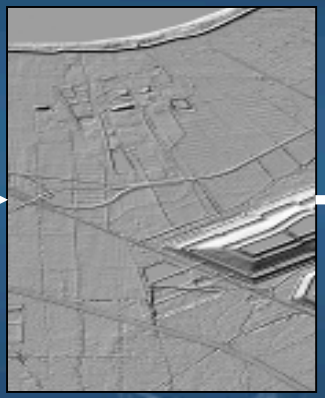
Accurate Lidar mapping is highly relevant to several data layers of The National Map



•Lidar



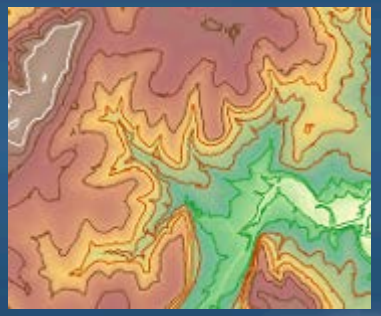
•Land Cover



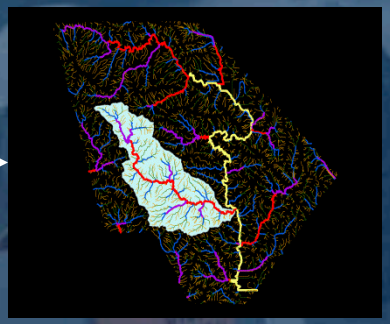
•Bare Earth
•Elevation

•Structures

•Orthoimagery

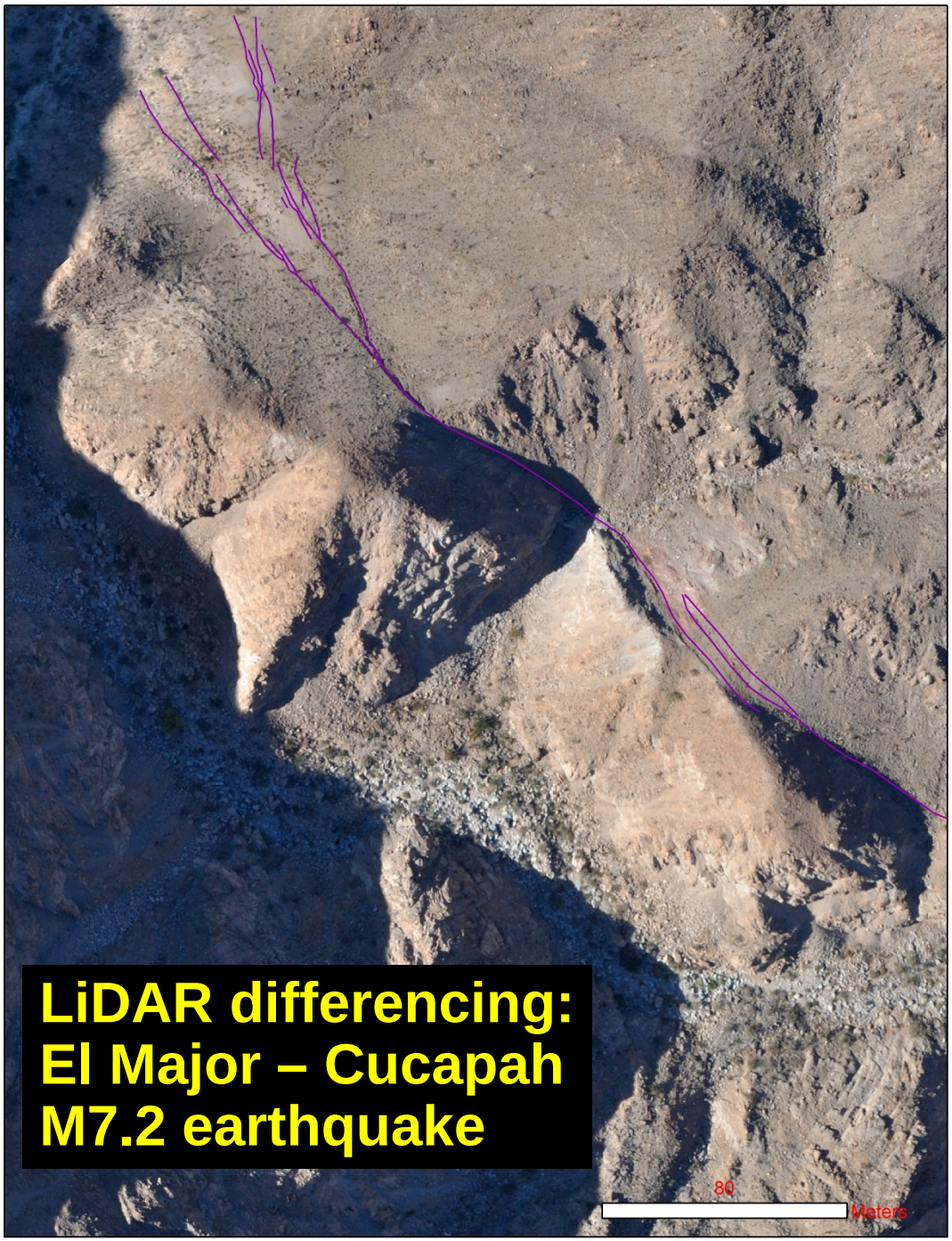


•Contours

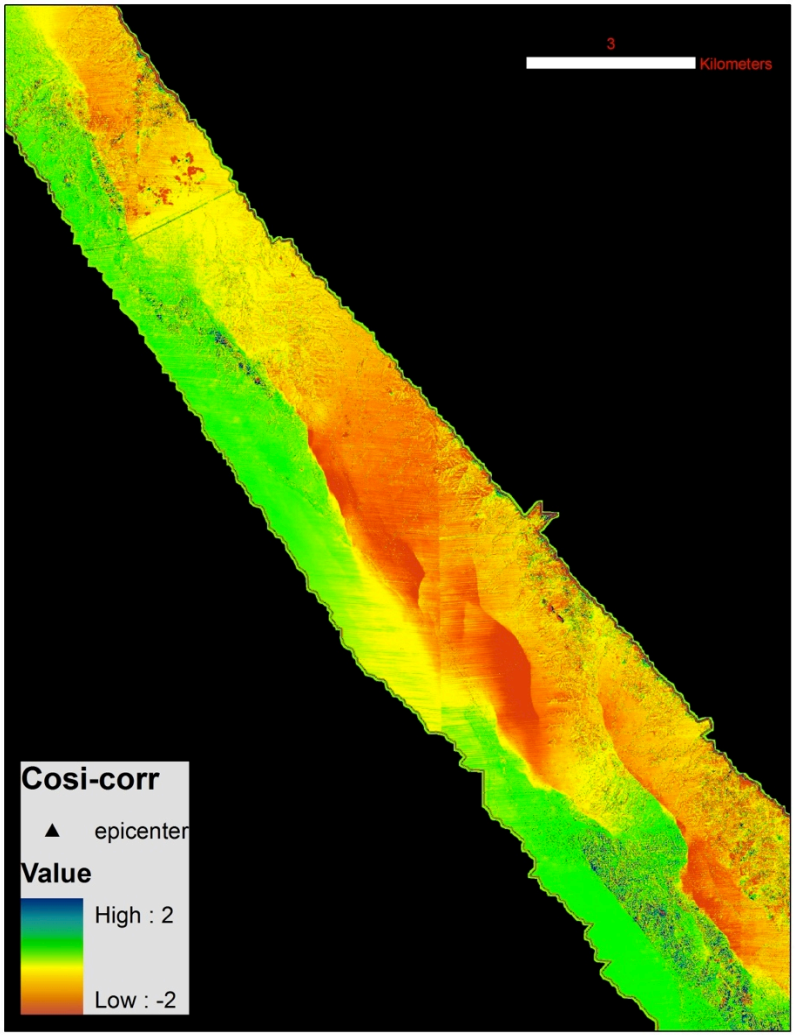


•Hydrology

USGS



LiDAR differencing: El Major – Cucapah M7.2 earthquake

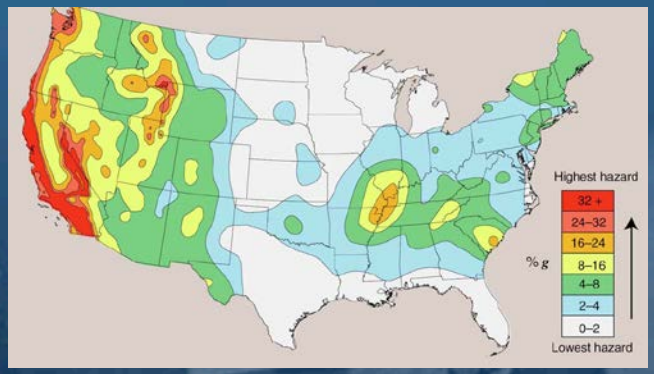


GPS enables ultra-high-precision georeferencing for fault mapping using repeat-pass imagery

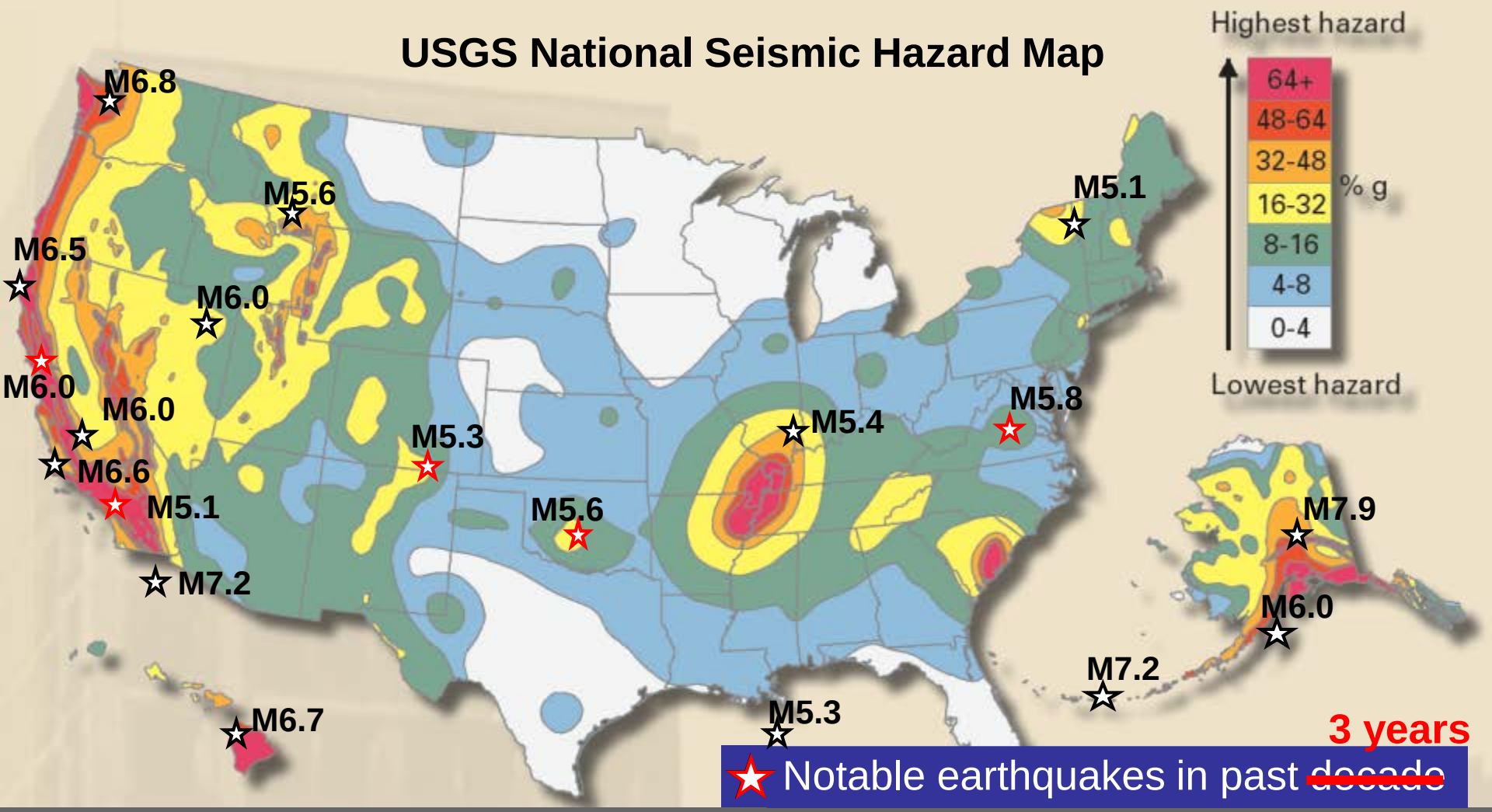
- **LiDAR**
- **3D stereo**

The USGS role in the National Earthquake Hazard Reduction Program partnership

- Provide earthquake monitoring and notifications,
- Assess seismic hazards,
- Conduct targeted research needed to reduce the risk from earthquake hazards nationwide, and
- Work with NEHRP agencies and many other partners to support public awareness of earthquake hazards and impacts.



Earthquakes are a national hazard



FEMA

NIST National Institute of Standards and Technology

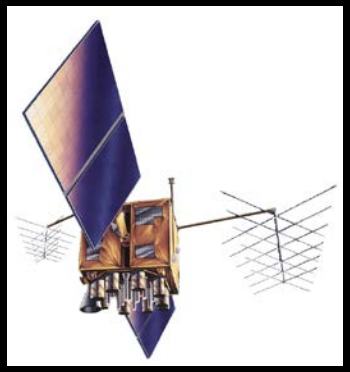
NSF

USGS science for a changing world

nehrp

national earthquake hazards reduction program

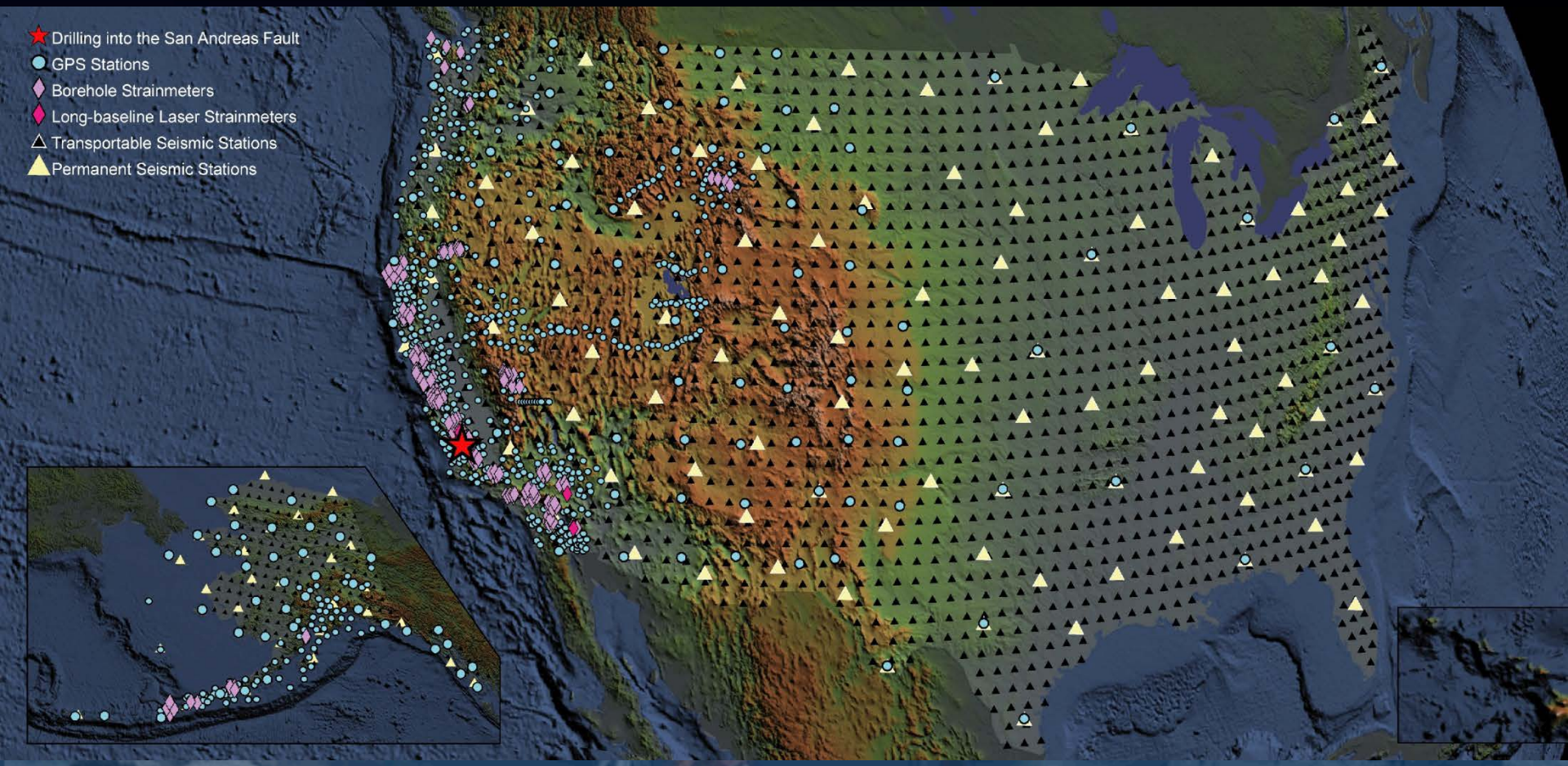
SCIGN
SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK



A network of GPS/GNSS stations measures plate tectonic motions to an accuracy of better than

1 mm/yr

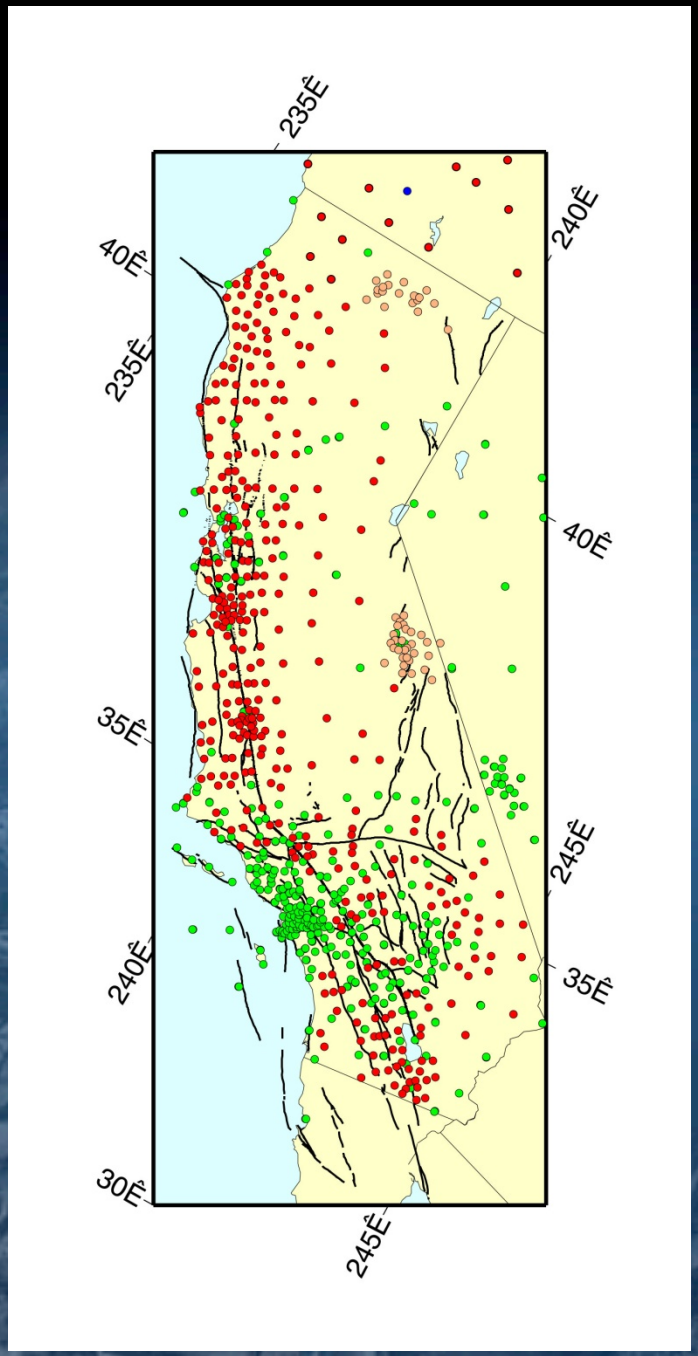
We can see whether the **motion** is ‘slow and steady,’ or perhaps more interestingly, it may **sometimes accelerate or decelerate**



earth scope PROJECT

USGS

National Science Foundation
WHERE DISCOVERIES BEGIN



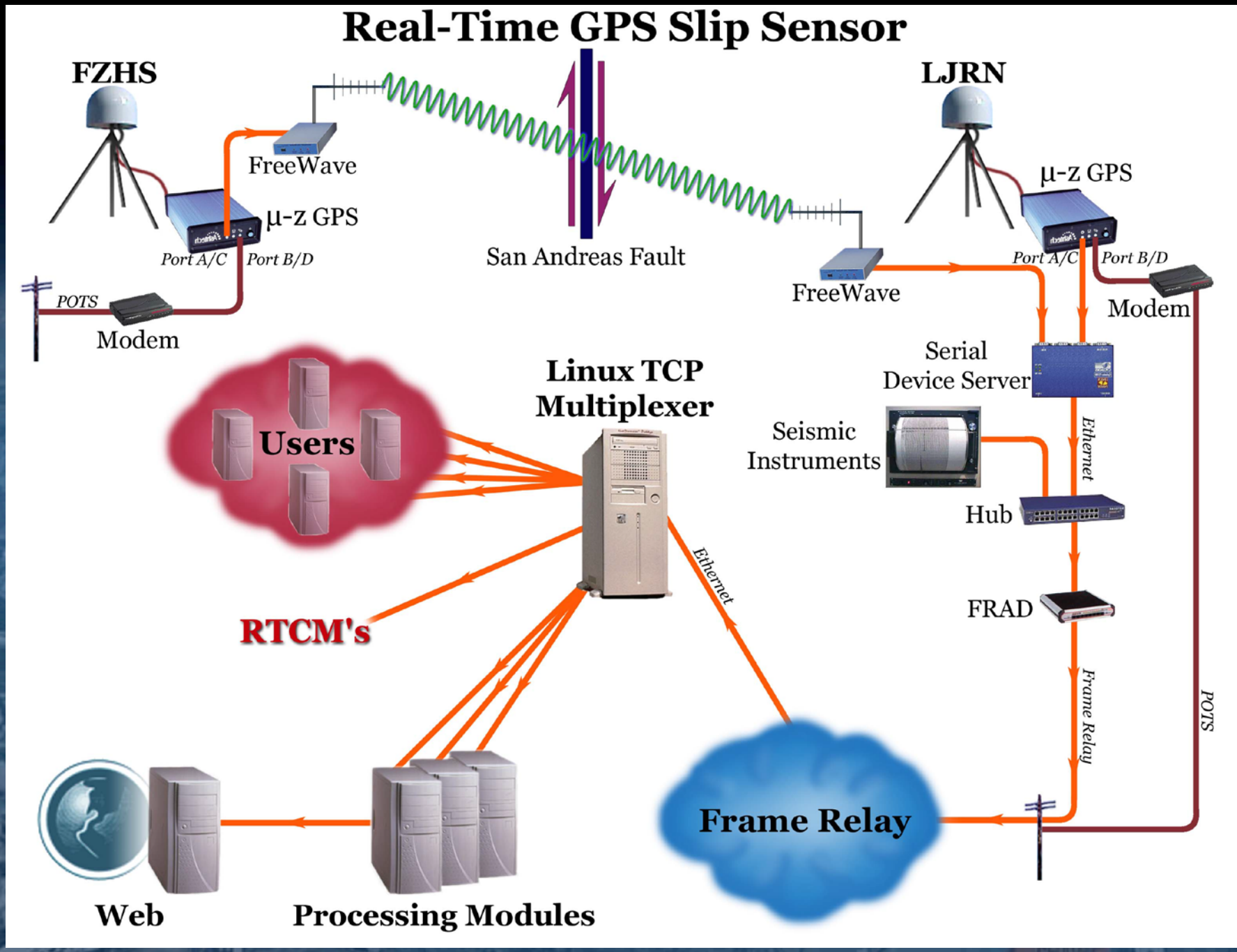
A New View Into Earth

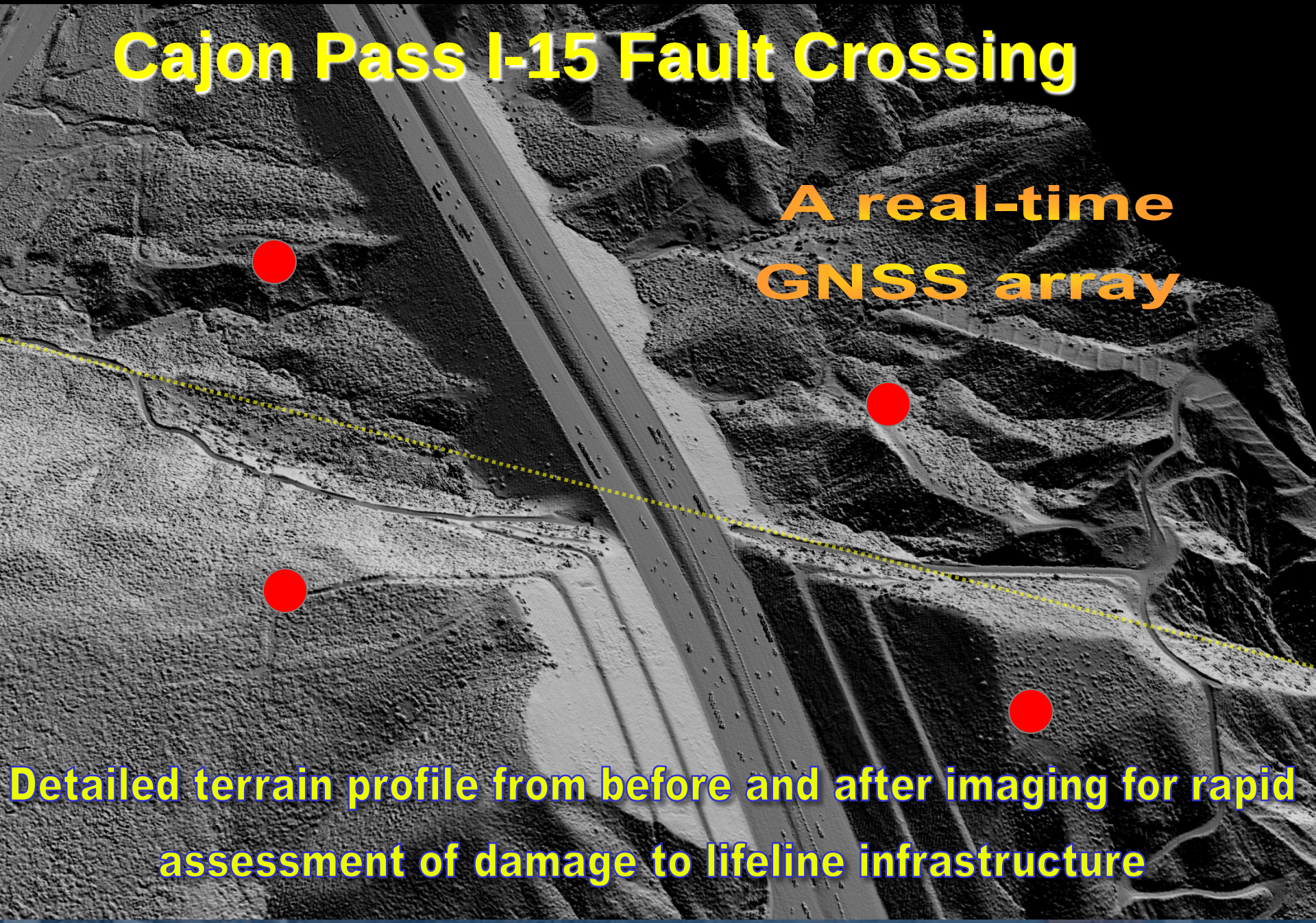
earthscope

Plate Boundary Observatory

San Andreas plan

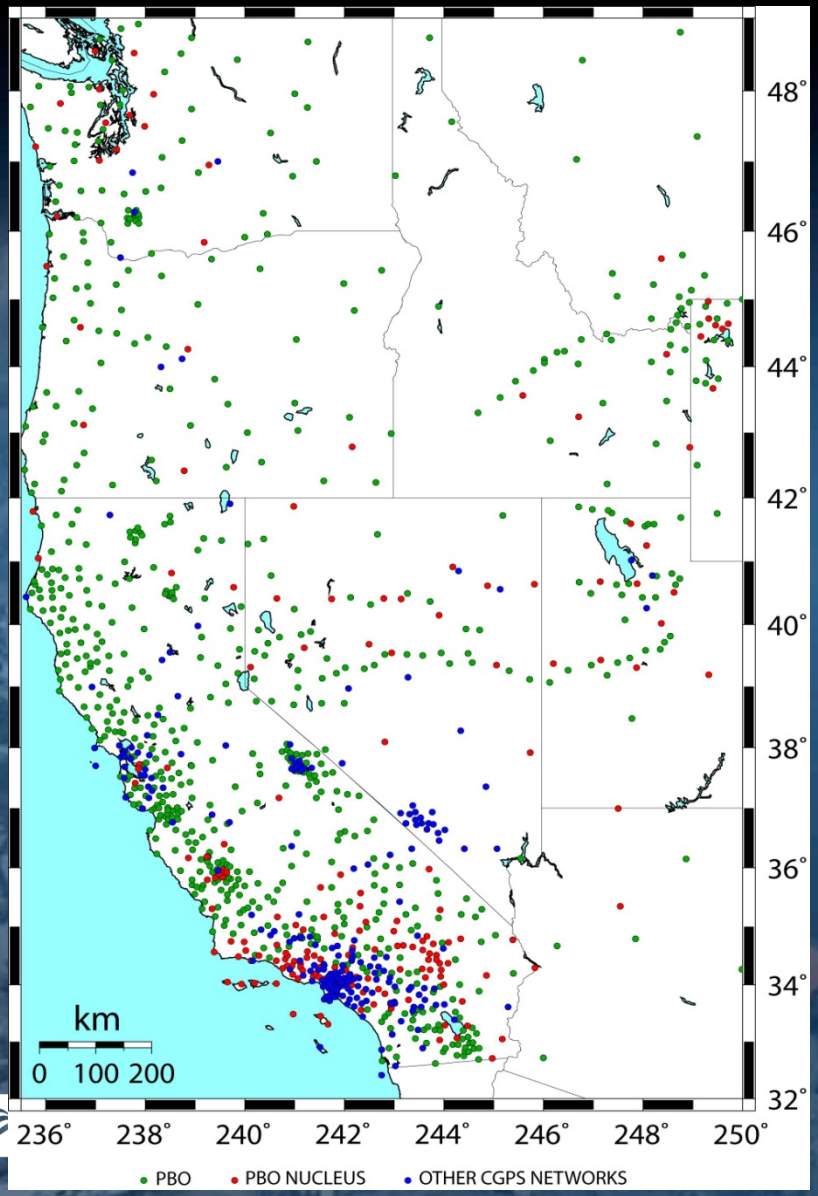
GNSS station clusters along San Andreas fault, especially along transitions from creeping to locked sections


Real-Time GPS Slip Sensor
FZHS
FreeWave
µ-z GPS
Port A/C
Port B/D
POTS
Modem
San Andreas Fault
LJRN
FreeWave
µ-z GPS
Port A/C
Port B/D
Modem
Serial
Device Server
Seismic
Instruments
Ethernet
Hub
FRAD
Frame Relay
POTS
Linux TCP
Multiplexer
Users
RTCM's
Ethernet
Frame Relay
Web
Processing Modules

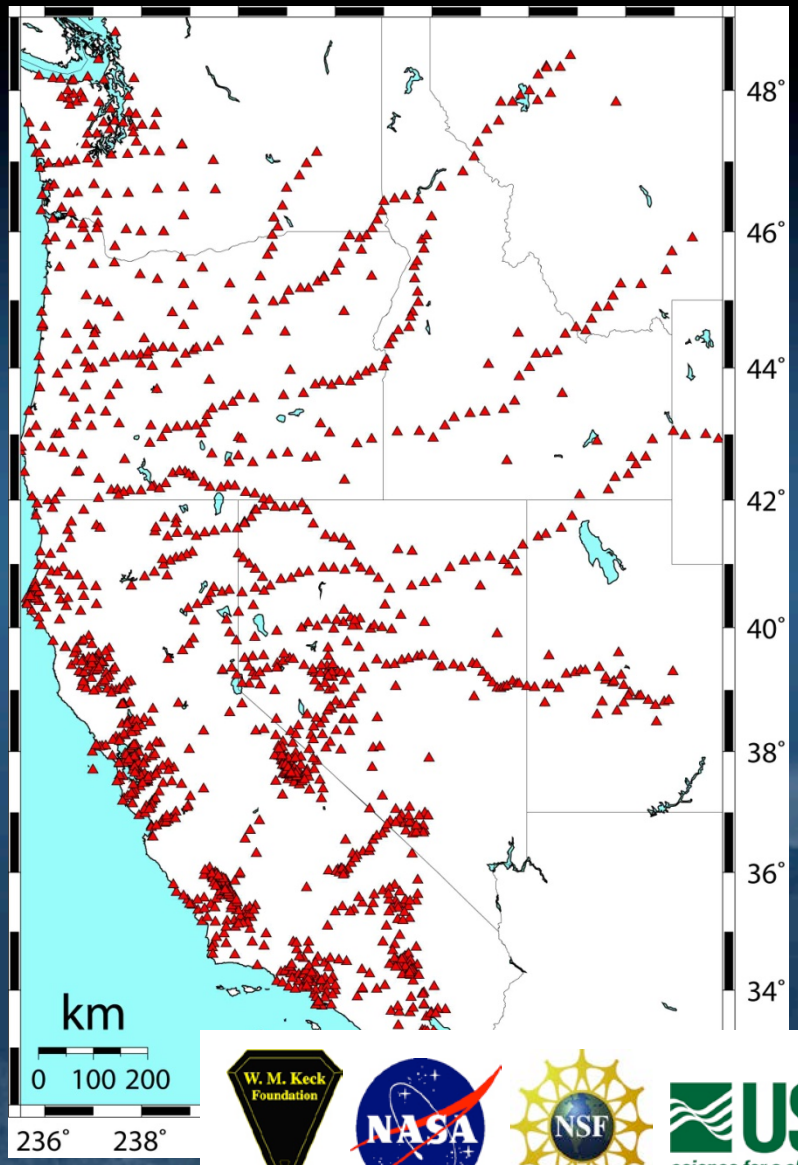

Cajon Pass I-15 Fault Crossing
A real-time
GNSS array
Detailed terrain profile from before and after imaging for rapid
assessment of damage to lifeline infrastructure

Continuous and campaign GPS arrays

Continuously Operating GPS Stations



Campaign Survey GPS Points



W. M. Keck Foundation

NASA

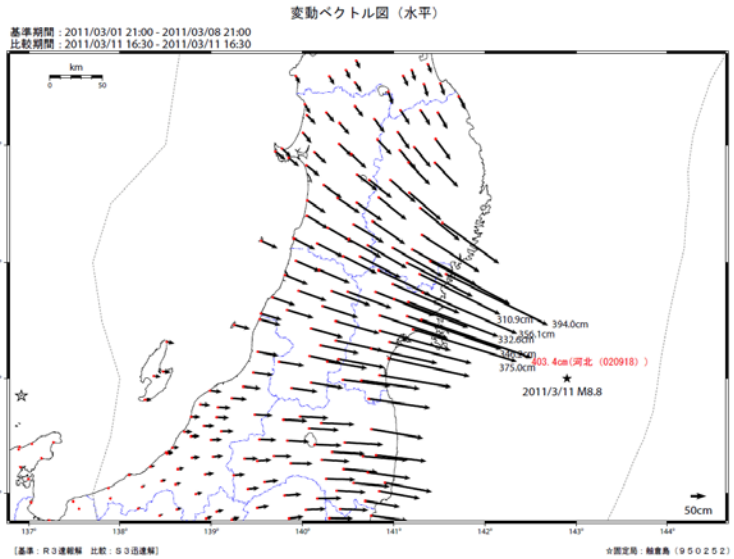
NSF

USGS science for a changing world

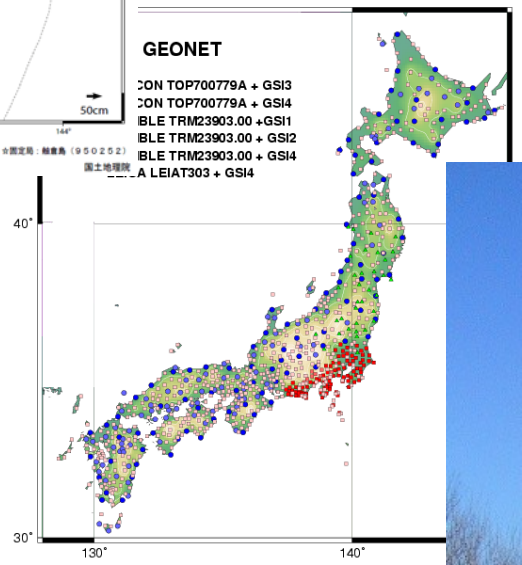
March 11, 2011 Japan earthquake

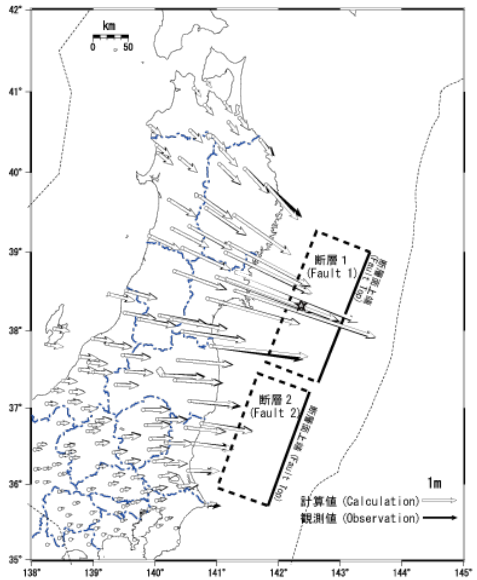
Initial GPS results from GSI showed 2.6 meters shift; later results gave maximum GPS offset of 4.034 m (13.2 feet)

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



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.





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)

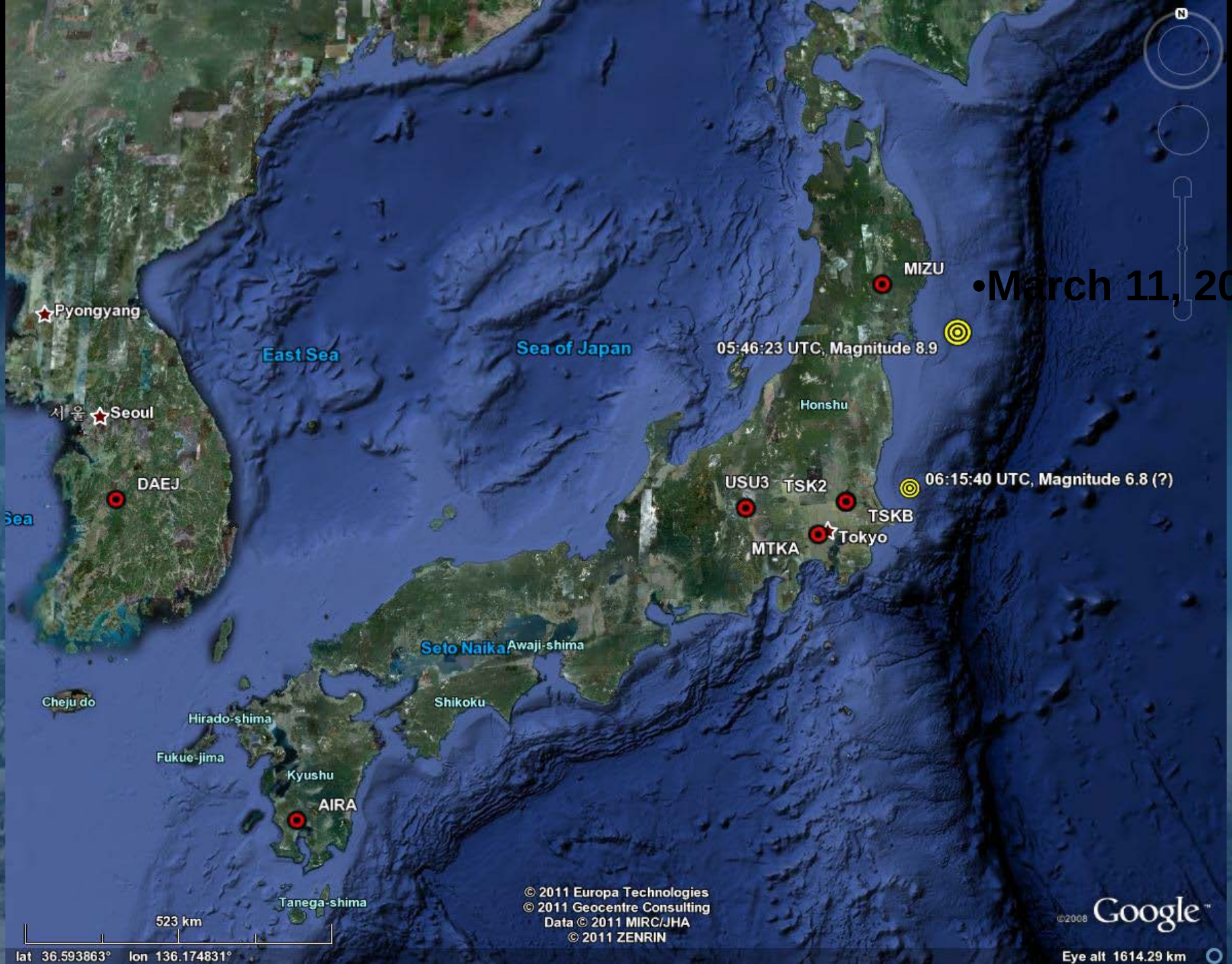
	緯度 Lat	経度 Lon	上端深さ Depth Fault Top km	長さ Length km	幅 Width km	走向 Strike	傾斜角 Dip	すべり角 Rake	すべり量 Slip m	Mw
断層1	39.00°	143.49°	10.0	199	85	202°	18°	97°	27.7	8.7
断層2	37.21°	142.51°	10.1	176	82	201°	15°	81°	5.9	8.2

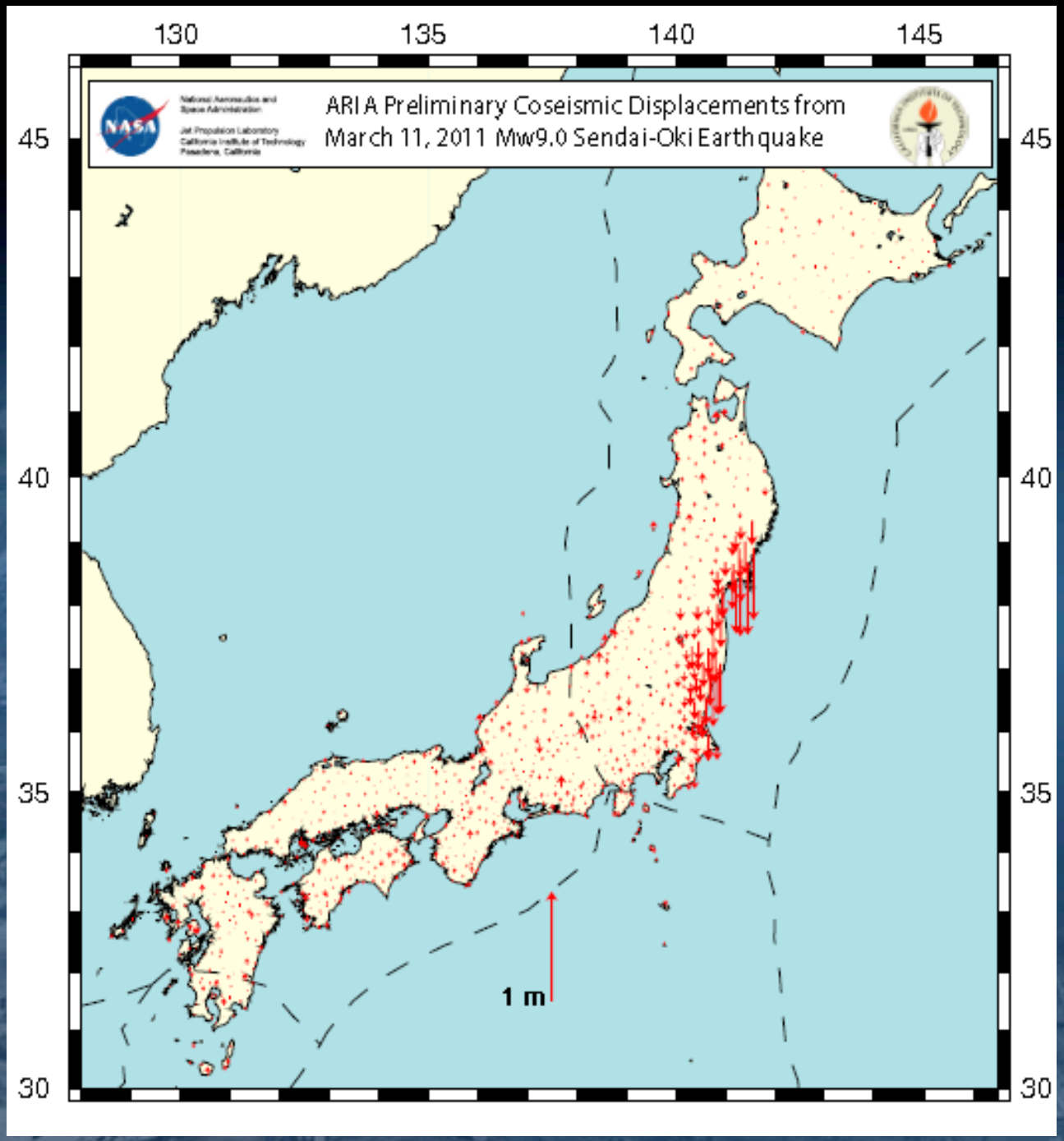
国土地理院資料
Geospatial Information Authority of Japan

Post-seismic:

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

USGS science for a changing world


•March 11, 201
MIZU
Pyongyang
East Sea
Sea of Japan
05:46:23 UTC, Magnitude 8.9
Honshu
서울 Seoul
DAEJ
USU3
TSK2
06:15:40 UTC, Magnitude 6.8 (?)
TSKB
Tokyo
MTKA
Seto Naika
Awaji-shima
Cheju do
Shikoku
Hirado-shima
Fukue-jima
Kyushu
AIRA
Tanega-shima
523 km
© 2011 Europa Technologies
© 2011 Geocentre Consulting
Data © 2011 MIRC/JHA
© 2011 ZENRIN
©2008 Google
lat 36.593863° lon 136.174831°
Eye alt 1614.29 km

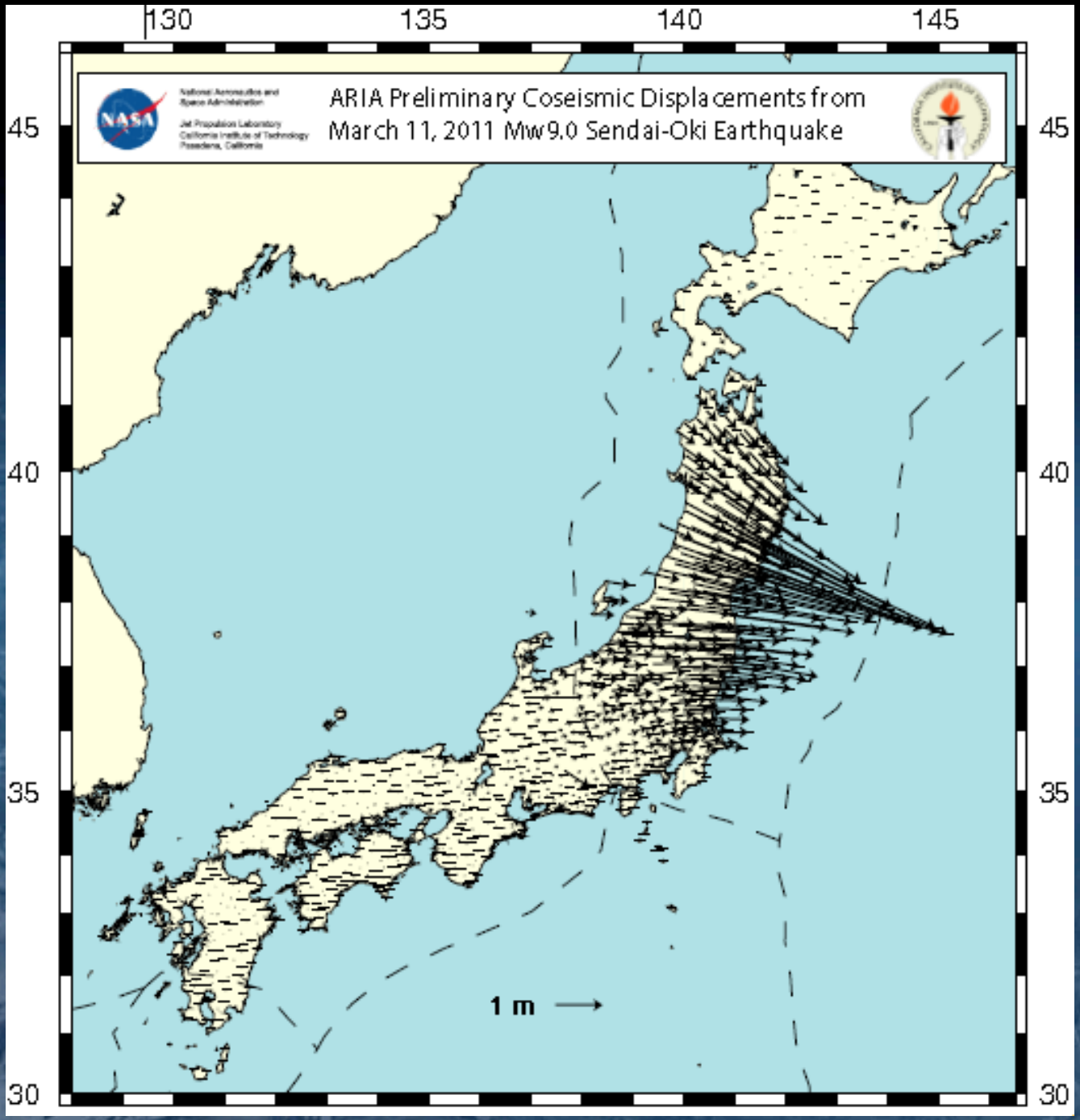


Vertical Displacements

Difference between estimated positions of GEONET stations at 05:00 and 06:30 UTC on March 11, 2011

Solutions by JPL and Caltech.

GPS 1 Hz data in RINEX format provided by the Geospatial Information Authority (GSI) of Japan.



Horizontal Displacements

Difference between estimated positions of GEONET stations at 05:00 and 06:30 UTC, March 11, 2011

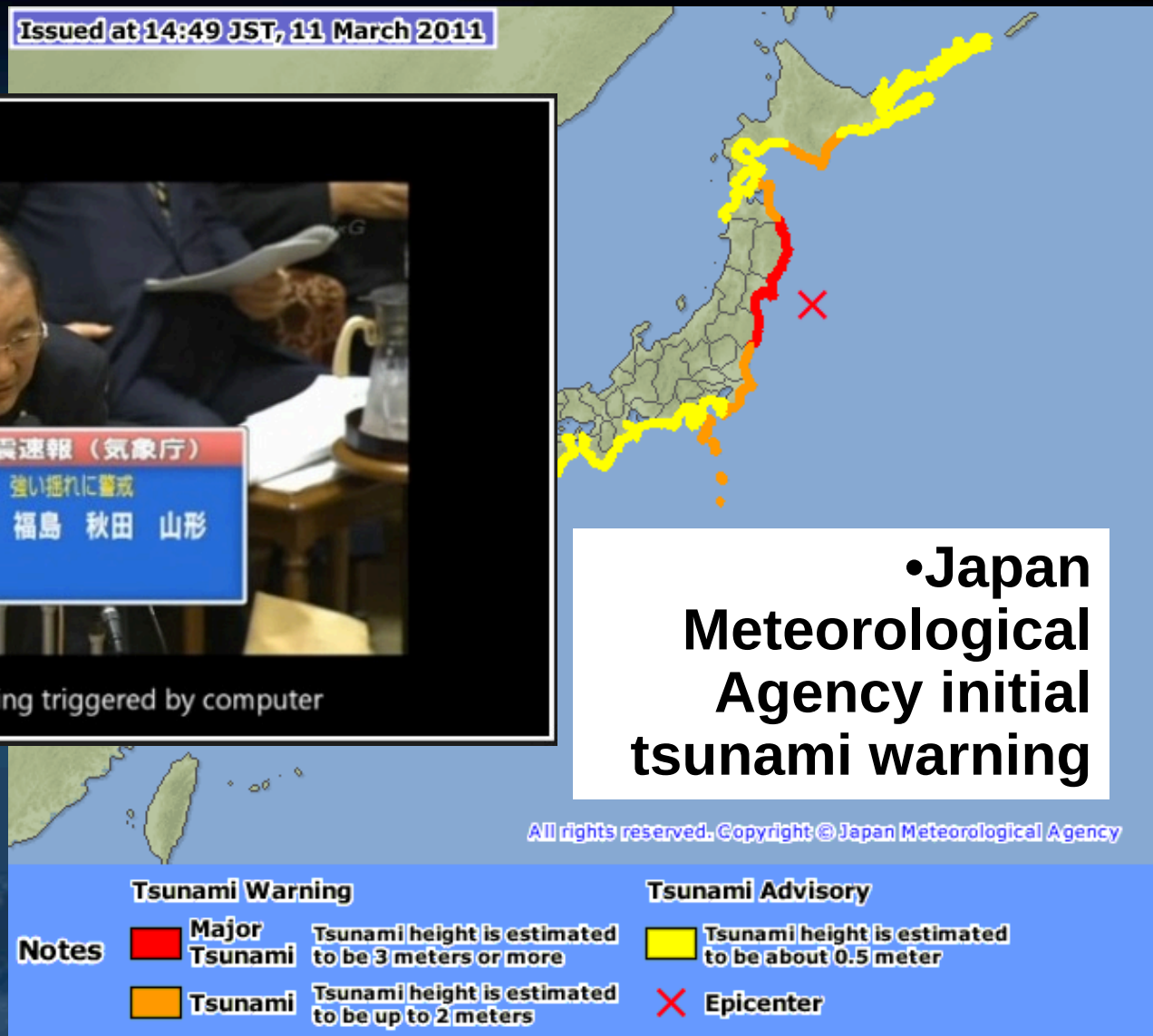
Bars at end of vector show 95% error estimate.

Solutions by JPL and Caltech.

GPS 1 Hz data in RINEX format provided by the Geospatial Information Authority (GSI) of Japan.

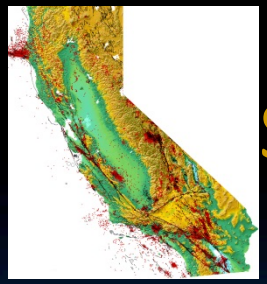
•Japanese early warning systems

Automatic earthquake warning triggered by computer



•Japan Meteorological Agency initial tsunami warning

USGS nehrp



USGS Earthquake Early Warning

ShakeAlert

Status today:

Prototype system issuing alerts since Jan. 2012

- alerts issued for recent So. California quakes
- System upgrades ongoing in So. Calif. (DHS funds)

California OES tasked by legislature to find funding for statewide system – USGS engaged

Administration requested and Congress added $0.85M in 2014 to USGS (total funding $1.45M)

Cost estimate and implementation plan complete for west-coast system

USGS

CAL E·M·A

GORDON AND BETTY MOORE FOUNDATION

Receiving alerts today:

- research scientists
- Google.org
- BART
- Metrolink
- Amgen
- So Cal Edison
- CalEMA
- SF DEM
- L.A. City
- L.A. County
- UC Berkeley OEP
- *more…*

BART

Google

SFDEM

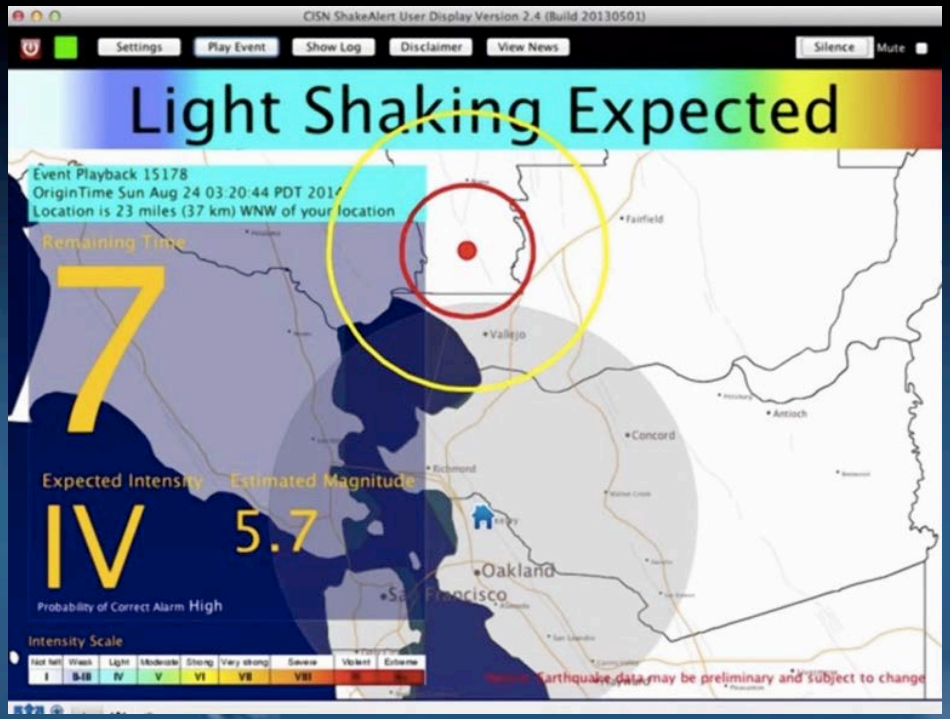
AMGEN

SOUTHERN CALIFORNIA EDISON

CITY of LOS ANGELES EMERGENCY MANAGEMENT DEPARTMENT

Earthquake early warning

- Earthquake early warning systems are currently in use in Japan and a number of other countries.
- Magnitude-6.0 South Napa earthquake provided the first major and successful test of the prototype *ShakeAlert* system in California.

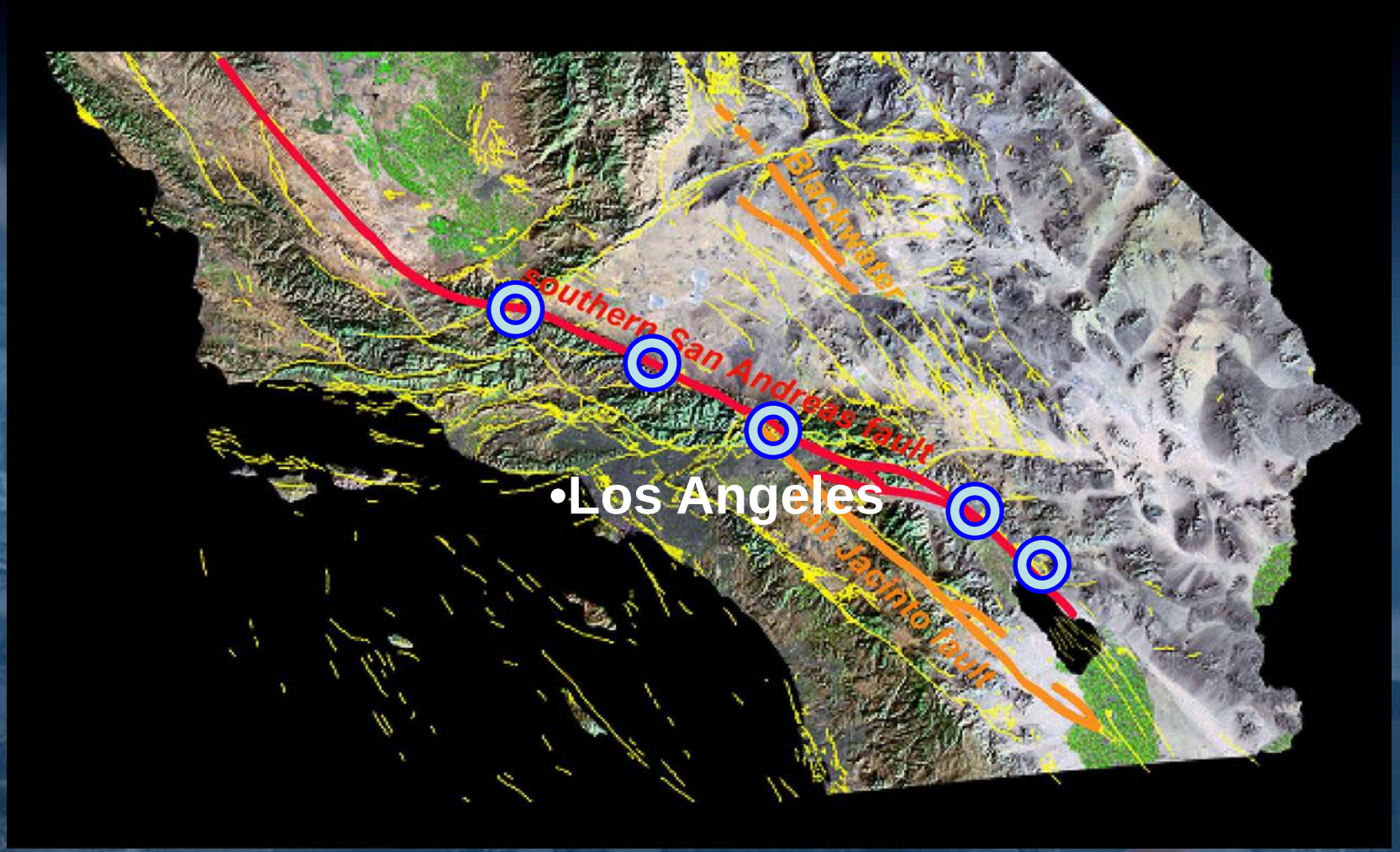


- Potential to provide additional situational awareness for critical infrastructure operators.

USGS

Image Source: UC Berkeley

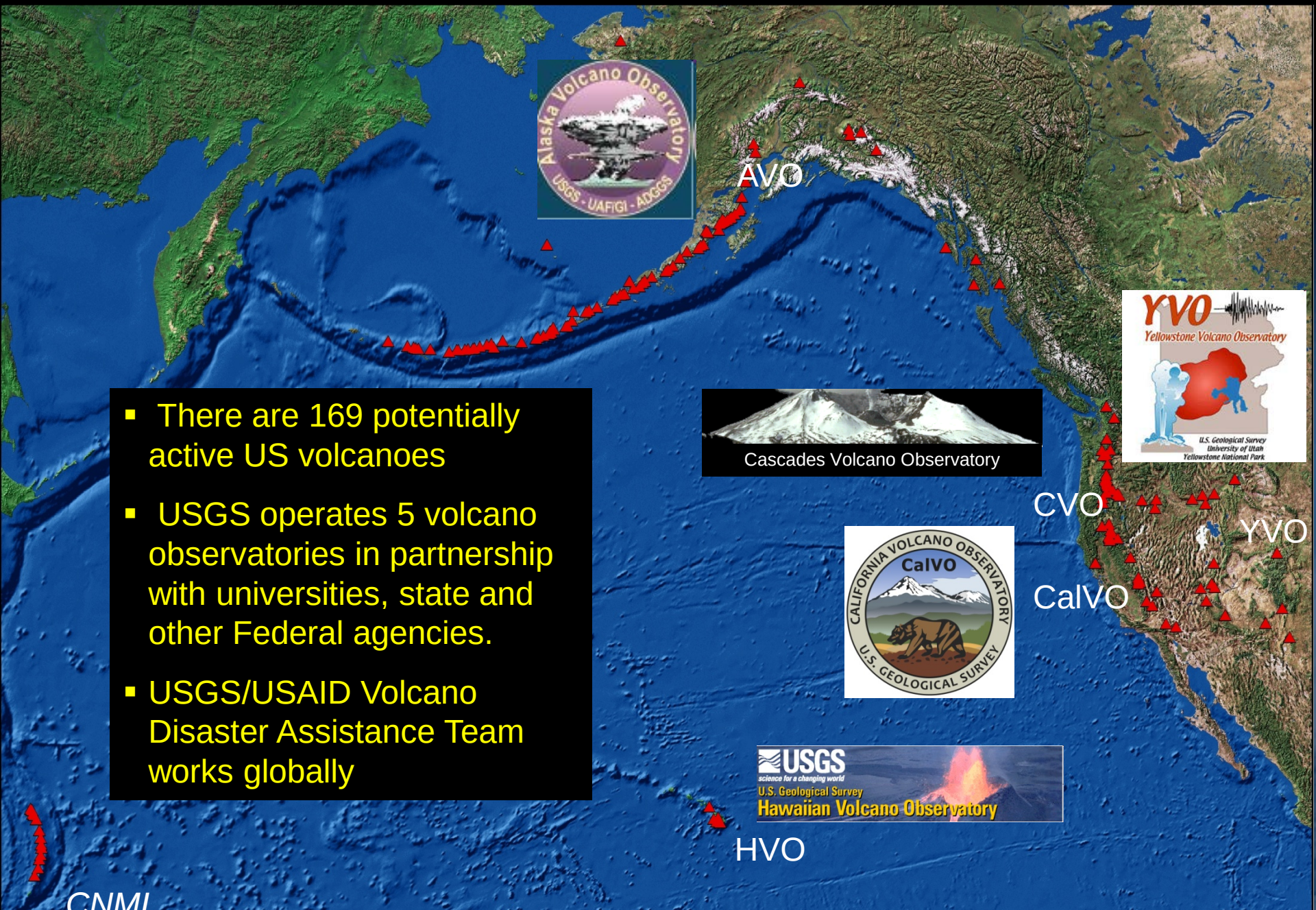
San Andreas Fault lifeline crossings



USGS

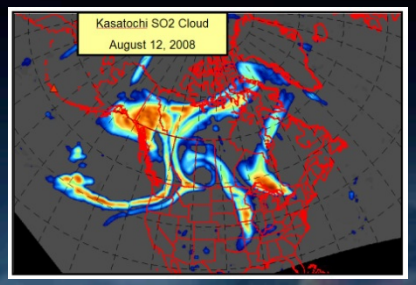
GPS & accelerometer arrays are being explored as part of a fully operational earthquake early warning system

USGS volcano monitoring responsibility



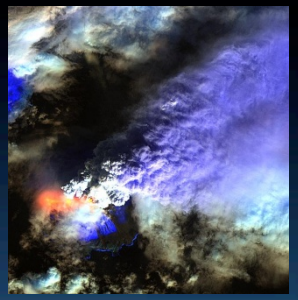
- There are 169 potentially active US volcanoes
- USGS operates 5 volcano observatories in partnership with universities, state and other Federal agencies.
- USGS/USAID Volcano Disaster Assistance Team works globally

USGS volcano observatories combine an array of real time data streams to interpret behavior and forecast eruptions

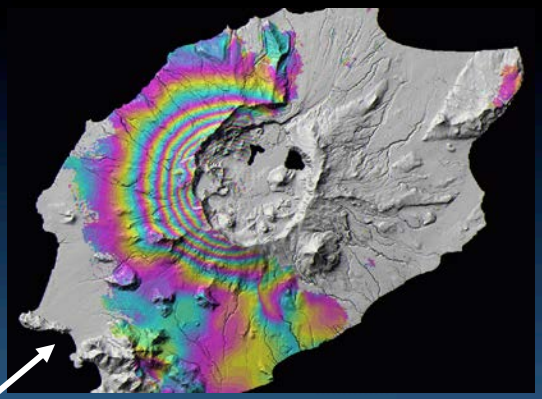


Gas cloud from satellite UV sensor

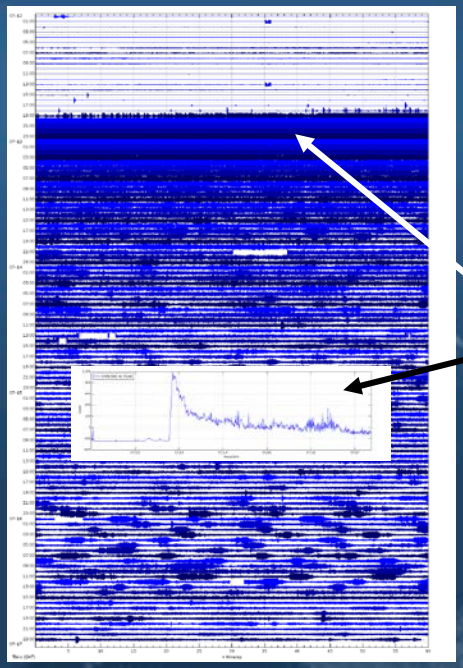
AVO operations room



Satellite surveillance for hotspots and ash

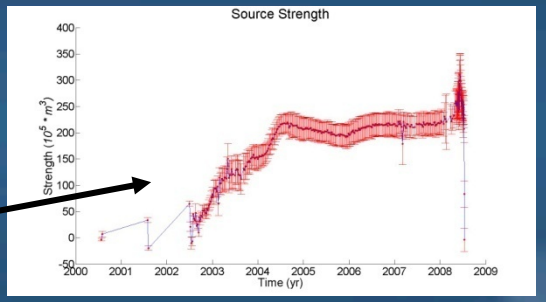


AVO field installation



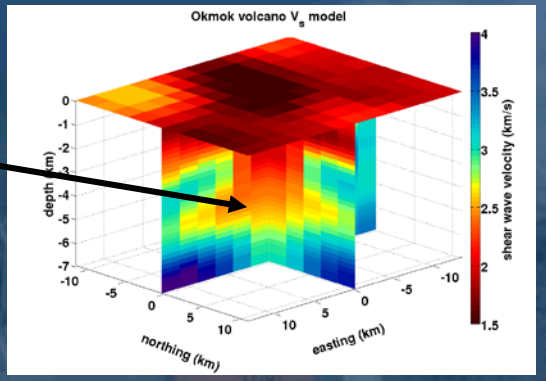
Volcano deformation from radar satellites

Volcano deformation from GPS



Eruption onset from seismic network

Magma chamber location from seismic tomography

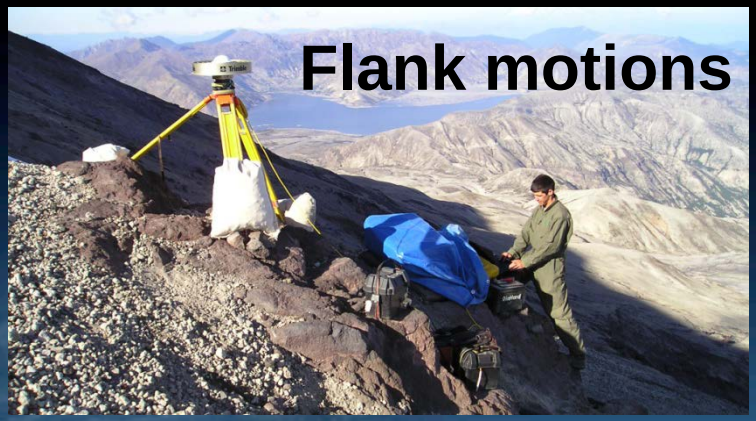


GPS uses by USGS Volcano Hazards Program

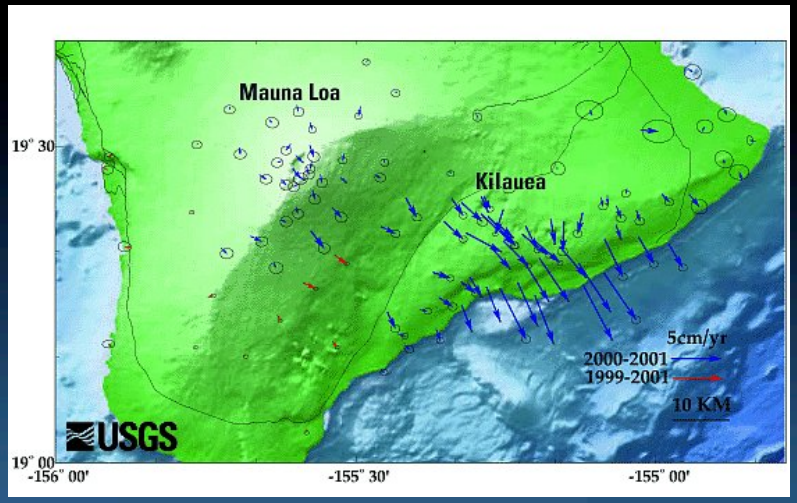
- **Key component of volcano monitoring for flank movements and lava dome growth**
- **Integral part of National Volcano Early Warning System plan for monitoring modernization and expansion**
- **Over 300 continuous GPS units are currently in use by USGS volcano observatories (nearly all of these are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

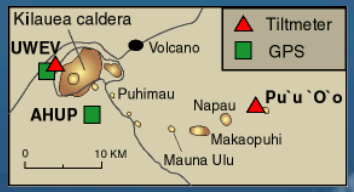
USGS

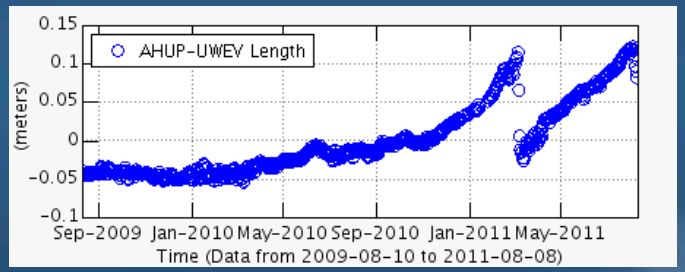
USGS uses precise GPS for eruption monitoring



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







USGS

National Volcano Early Warning System (NVIEWS): Closing the monitoring gap

Based on systematic threat ranking of 169 U.S. Volcanoes

NVEWS Goals:

- Robust real-time monitoring of the most threatening volcanoes.
- 24/7 Volcano Watch Office.
- Support for collaborative research and communication projects with State, Local and Academic partners.

Authorization bill pending before Senate Energy and Natural Resources Committee

USGS

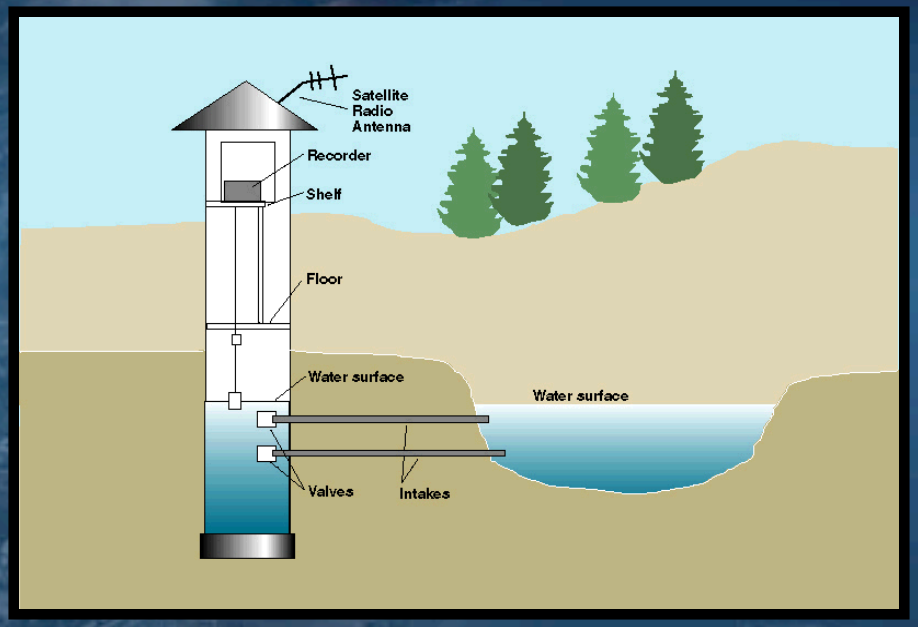
NVEWS TARGETS	MONITORING GAP
Kilauea, HI	1 ERUPTION
St. Helens, WA	1 ERUPTION
Rainier, WA	3
Hood, OR	3
Shasta, CA	3
South Sister, OR	3
Lassen, CA	3
Mauna Loa, HI	2
Redoubt, AK	2
Makushin. AK	2
Glacier Peak, WA	4
Akutan, AK	2
Baker, WA	3
Spurr, AK	2
Newberry Volcano,OR	3
Augustine, AK	2
Crater Lake, OR	4
Inyo Craters., CA	3
Adams, WA,	2

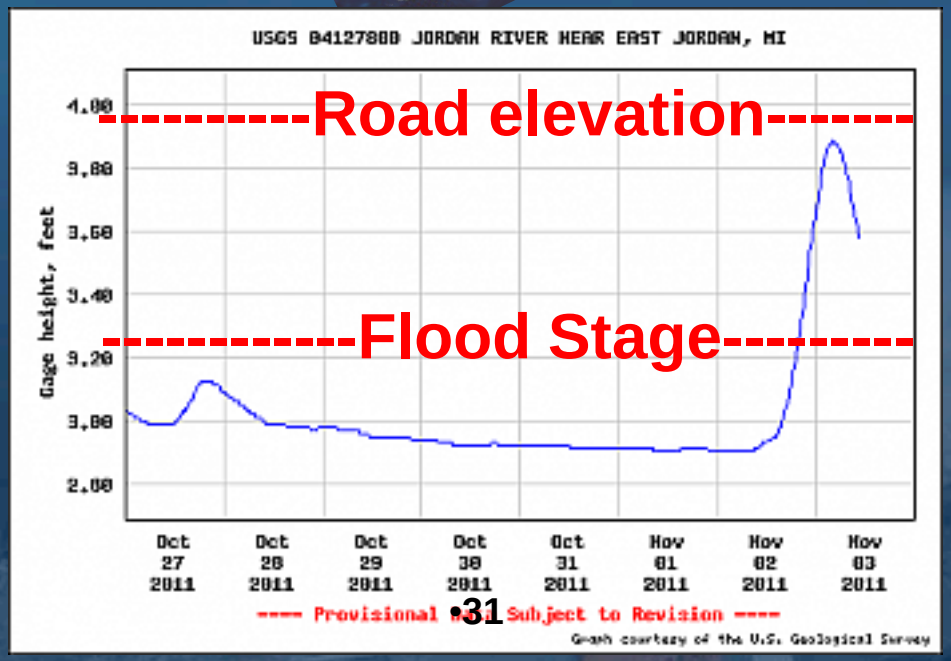
- **GPS used for Streamgaging**

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

USGS WaterAlert

Text message or e-mail customized alerts





http://water.usgs.gov/wateralert/

USGS

GPS/GNSS for hazards management

- **GPS/GNSS is an essential enabling technology for the mapping and precise monitoring needed to accomplish science missions in support of hazard warnings.**
- **In the aftermath of a significant disaster event, GPS/GNSS is critical in support of new mapping and geopositioning incident features - essential in support of immediate response (e.g., support Urban Search & Rescue) as well as for long-term recovery (e.g., organizing debris removal).**

USGS
science for a changing world


Questions?