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GPS Precision Monitoring of Natural Hazards

USTTI 2015 Course:

GPS Applications for Disaster Management

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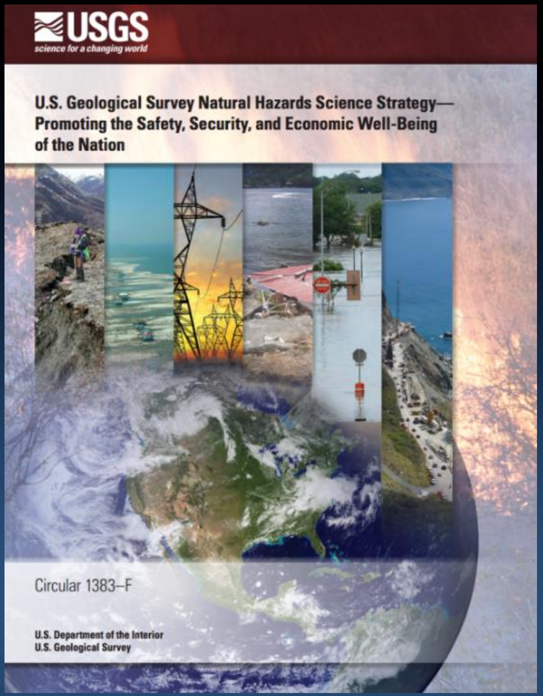
USGS Natural Hazards Science Strategy

- **Goal 1**: Enhanced observations
  - **GPS/GNSS, optical, LiDAR, InSAR and seismic**
- **Goal 2**: Fundamental understanding of hazards and impacts
- **Goal 3**: Improved assessment products and services
- **Goal 4**: Effective situational awareness



April 2013

USGS key natural 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

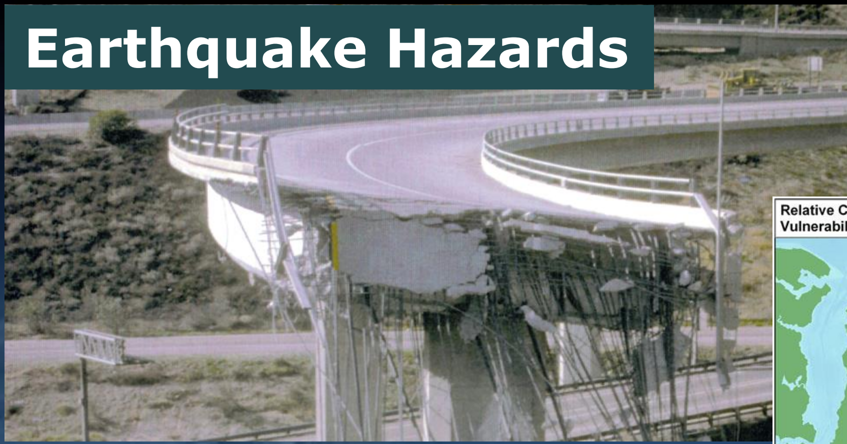




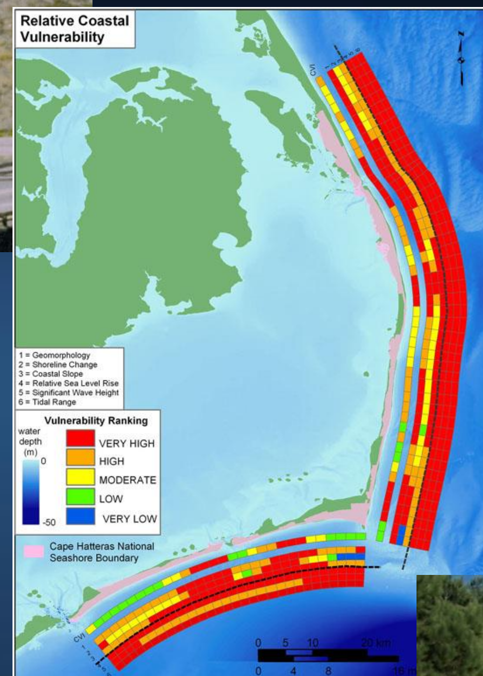



Natural Hazards Mission Area programs

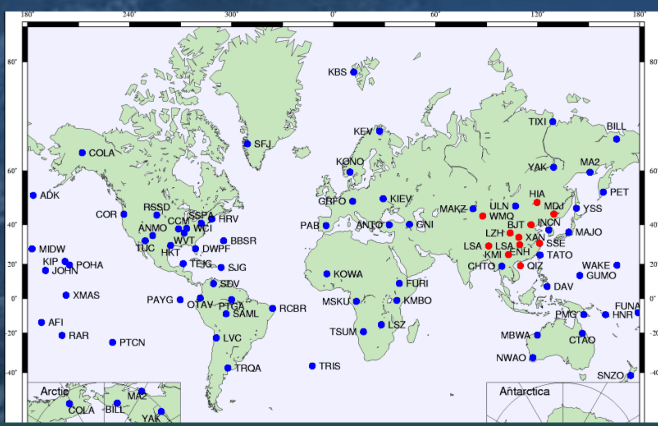
Earthquake Hazards



Volcano Hazards



Coastal & Marine Geology



Global Seismographic Network

Landslide Hazards

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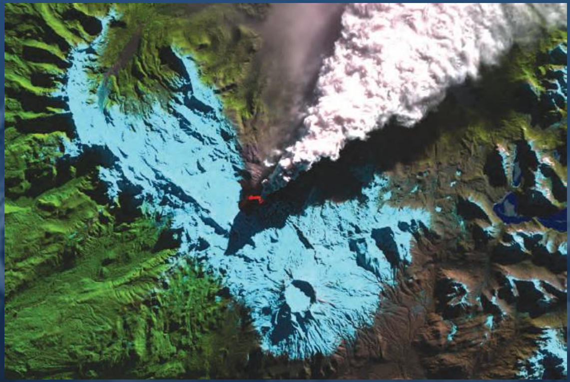
USGS Emergency Management

- The **Natural Hazards Mission Area** is responsibile for overseeing the USGS's emergency management activities.
- Function includes the USGS **Hazard Response Executive Committee**, which provides executive direction, oversight, and support to USGS managers in responding to major hazard events.
- During incidents of national significance, the USGS provides support to certain **National Response Framework** emergency support functions.



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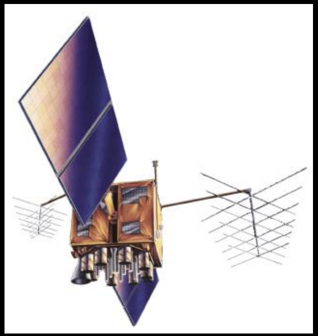
SCIGN
SOUTHERN CALIFORNIA
INTEGRATED GPS NETWORK

GPS/GNSS



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

1 mm/yr

We can see whether the motion is ‘slow and steady,’ or perhaps more interestingly, is it sometimes accelerating or decelerating

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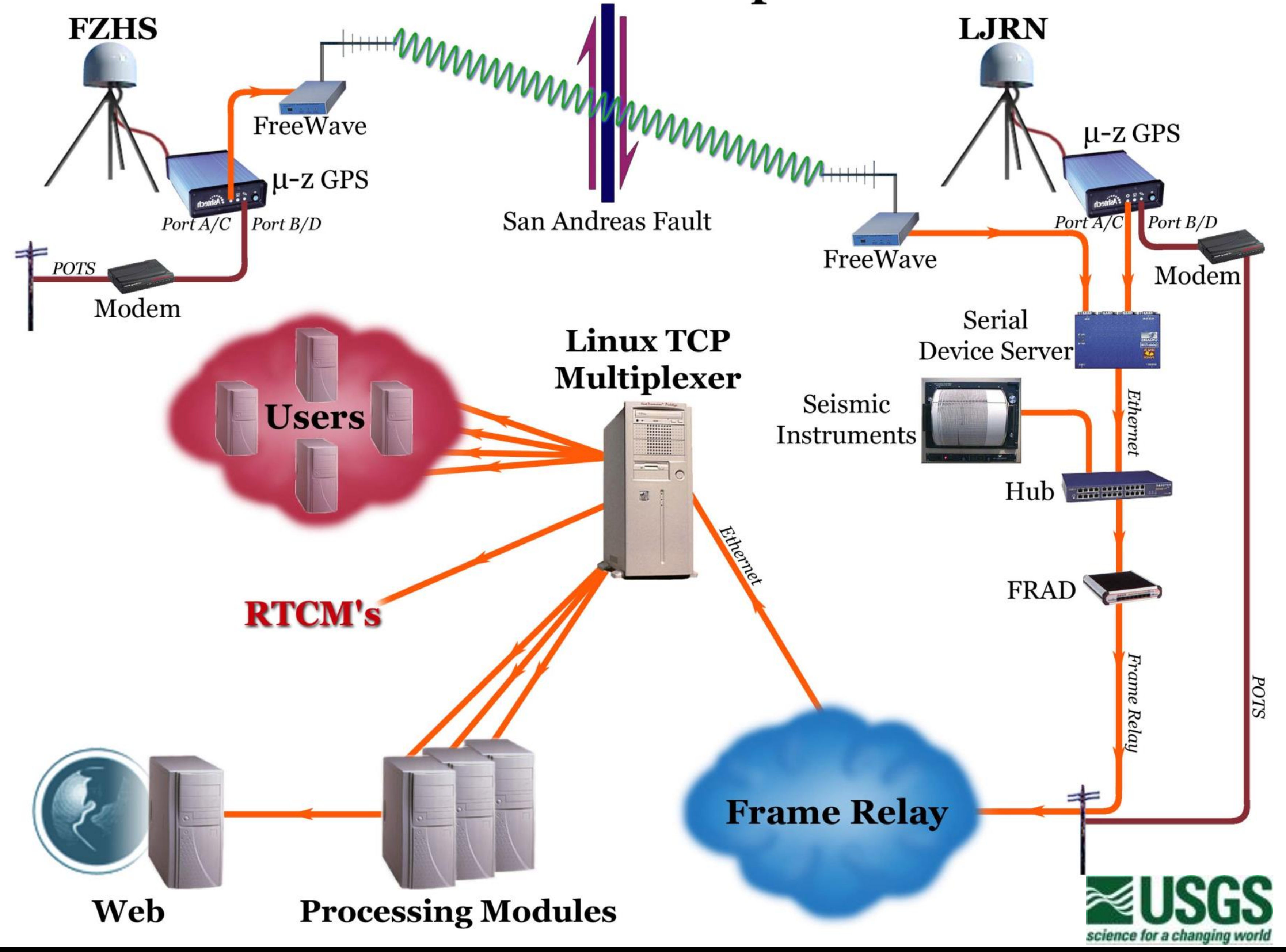
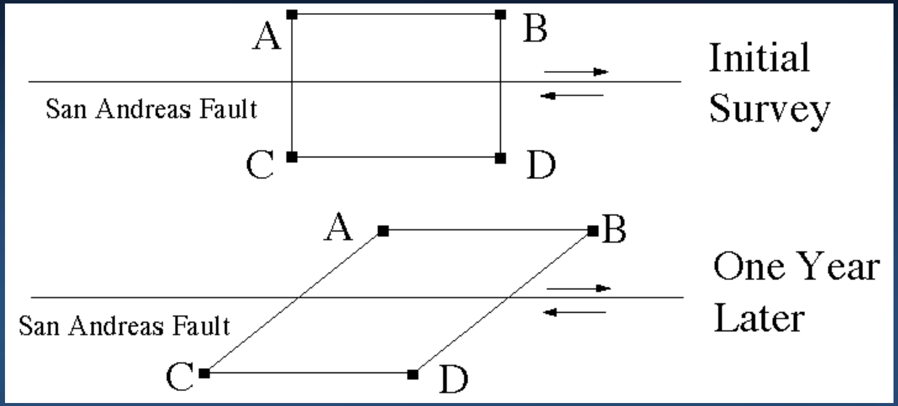
Real-Time GPS Slip Sensor



How does the USGS use GPS/GNSS to measure fault motion?

- **Objective:** determine how stations near active faults move relative to each other.
- **Occupy stations simultaneously.**
- **Relative positions and possible motion are determined** between stations separated by up to several 100 km to a precision of better than a few millimeters.



- Months or years later we **reoccupy the same stations**.
- **Determine the change in relative position** between stations.
- **Calculate accumulated strain and slip** between faults.

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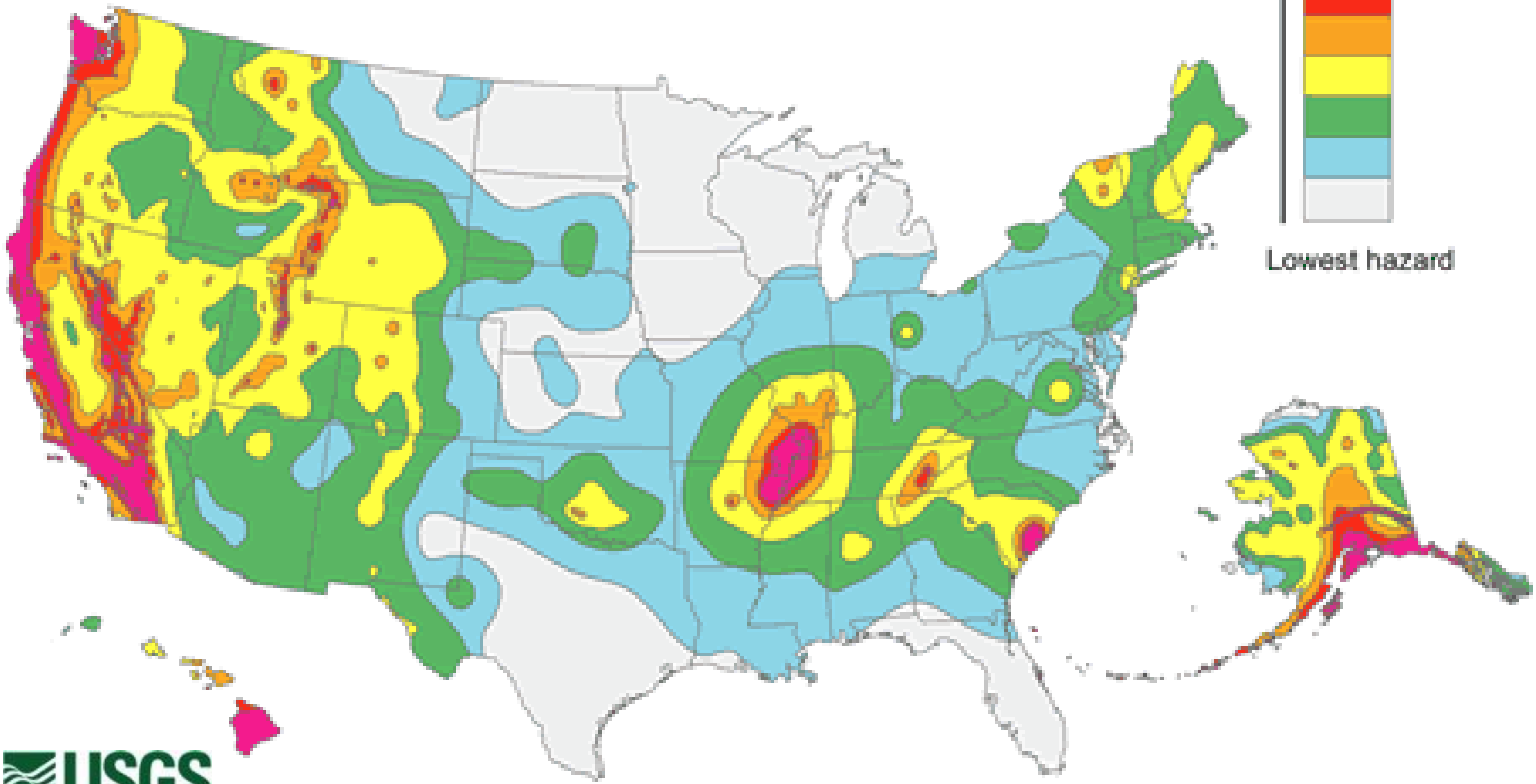
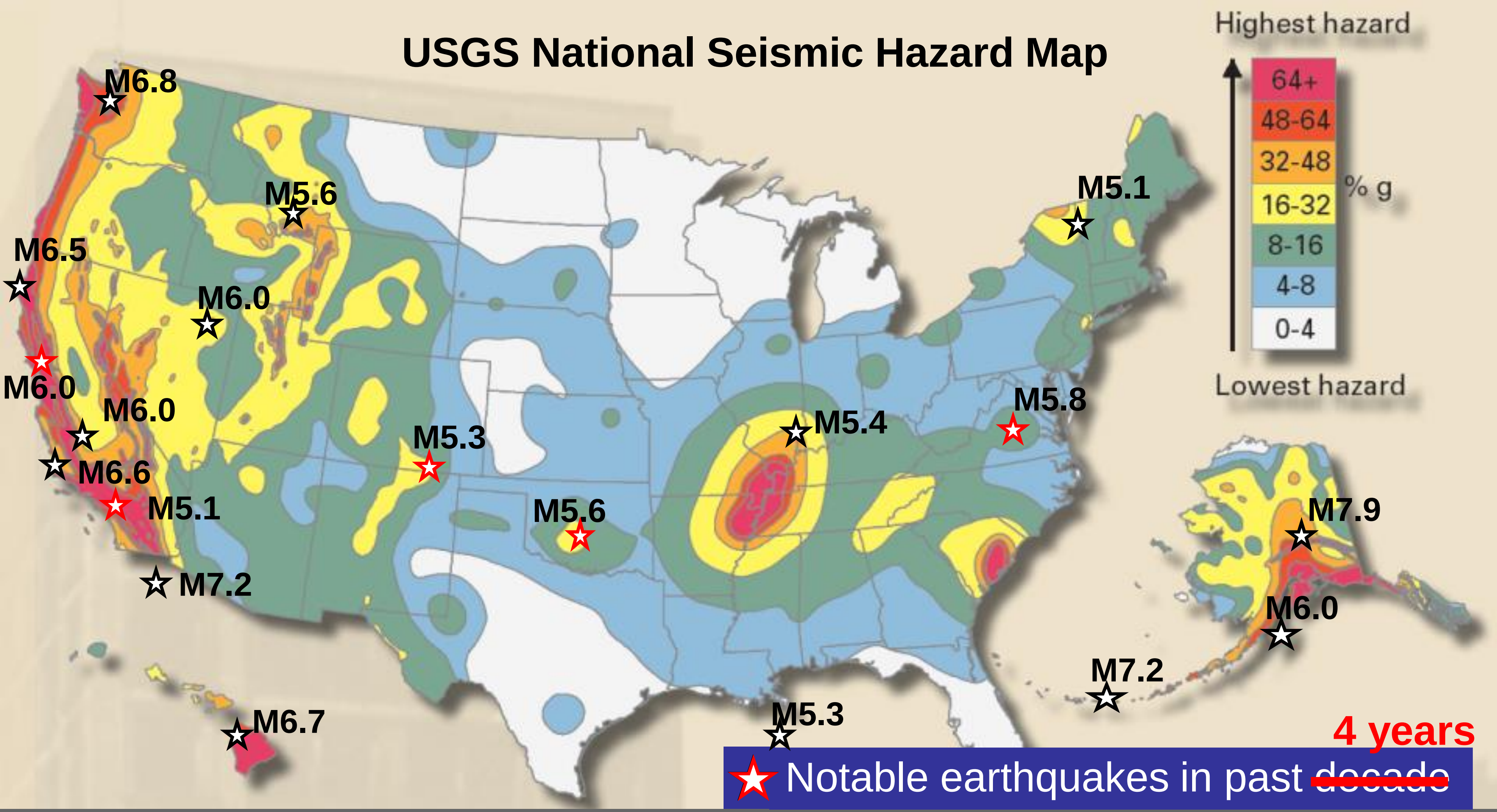
National Seismic Hazard Map, 2014



Earthquakes are a national hazard



FEMA

NIST National Institute of Standards and Technology

NSF

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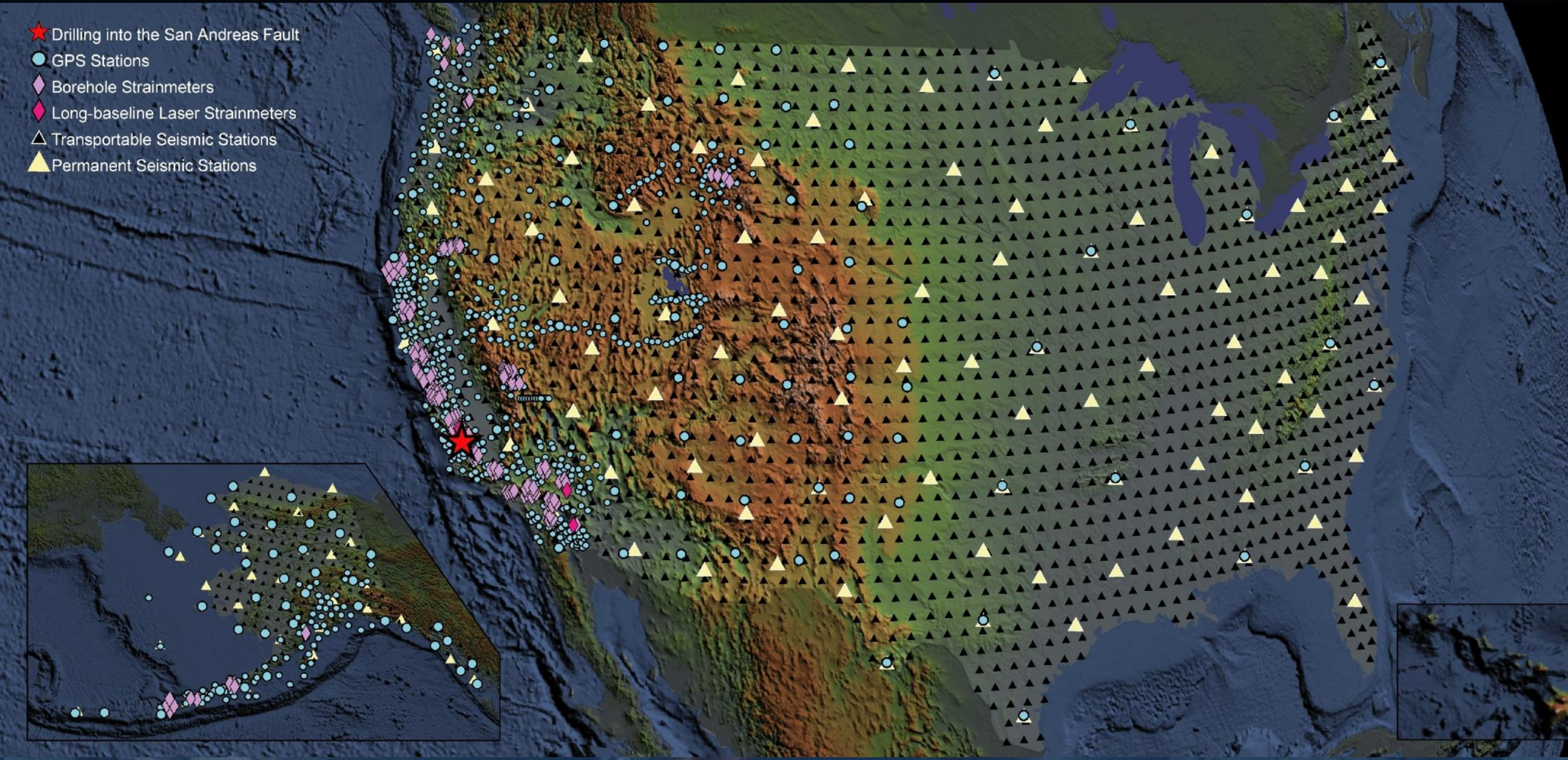
nehrp

national earthquake hazards reduction program earth scope PROJECT



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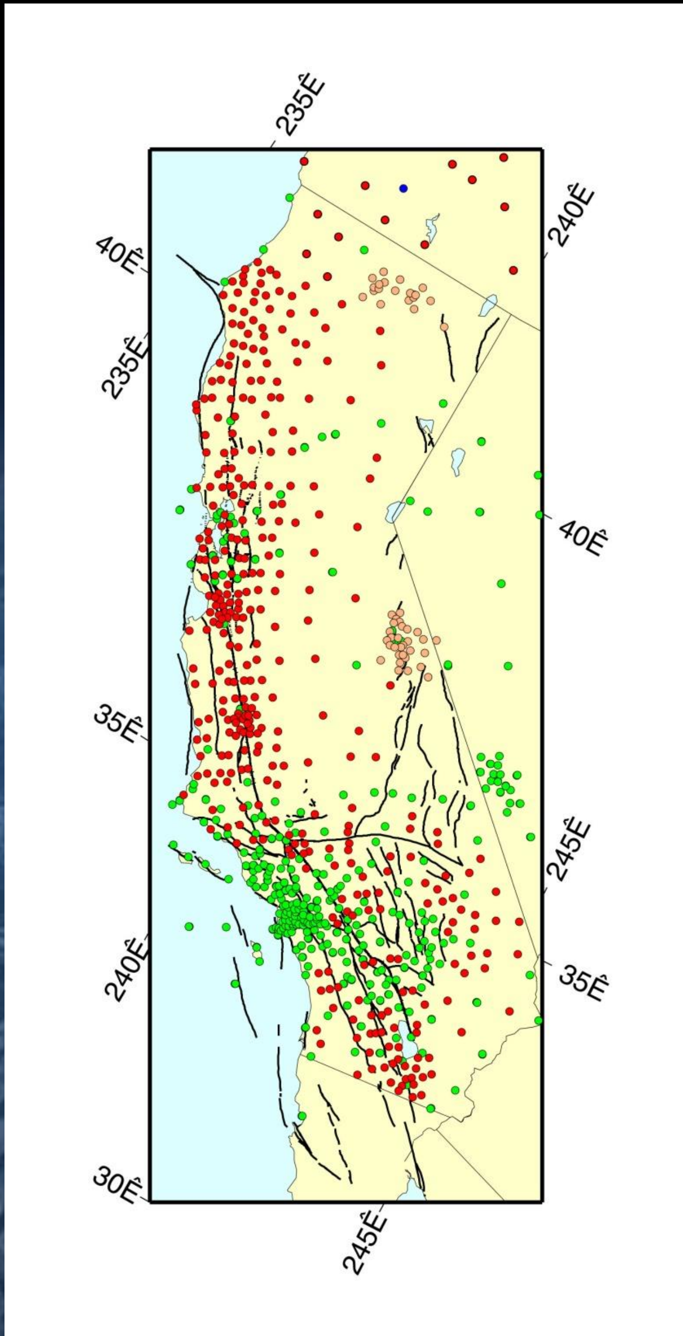
National Science Foundation
WHERE DISCOVERIES BEGIN



A New View Into Earth
earthscope

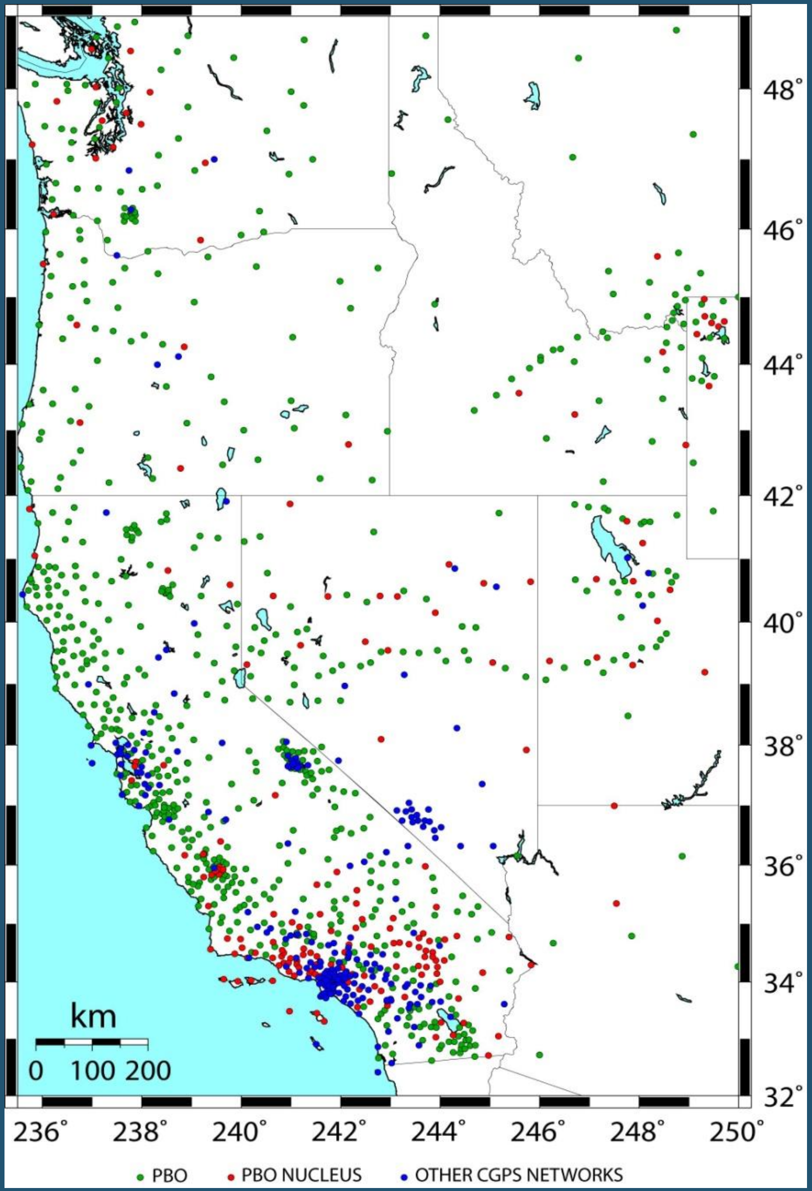
Plate Boundary Observatory

San Andreas plan

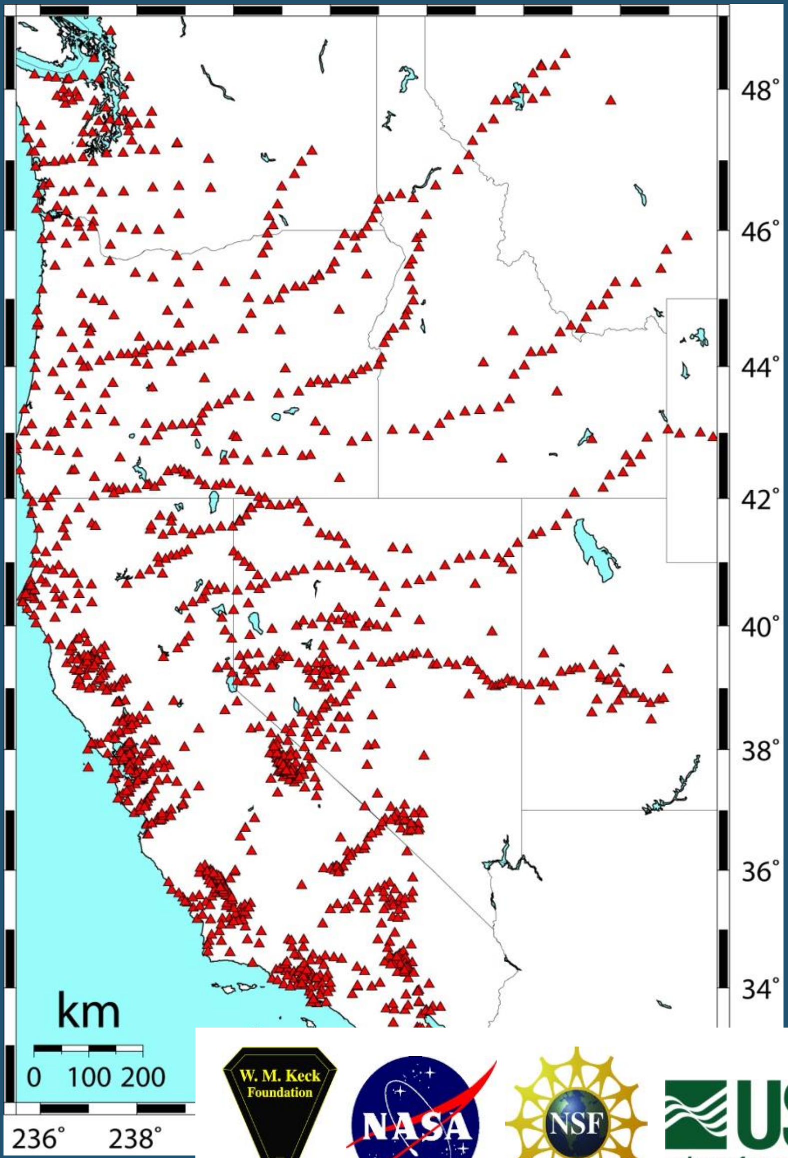
GNSS station clusters along San Andreas fault, especially along transitions from creeping to locked sections

Continuous and campaign GPS arrays

Continuously Operating GPS Stations



Campaign Survey GPS Points



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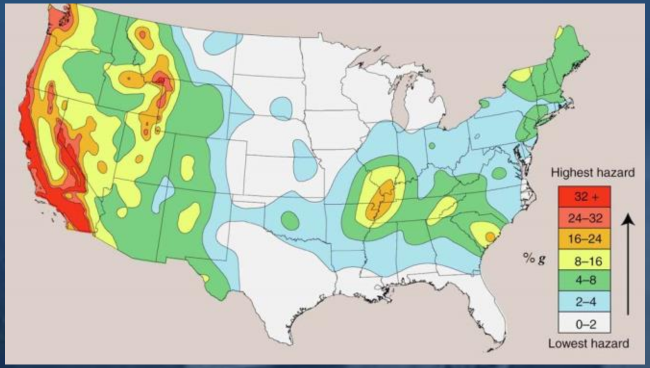
The USGS role in the National Earthquake Hazard Reduction Program partnership

- 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.



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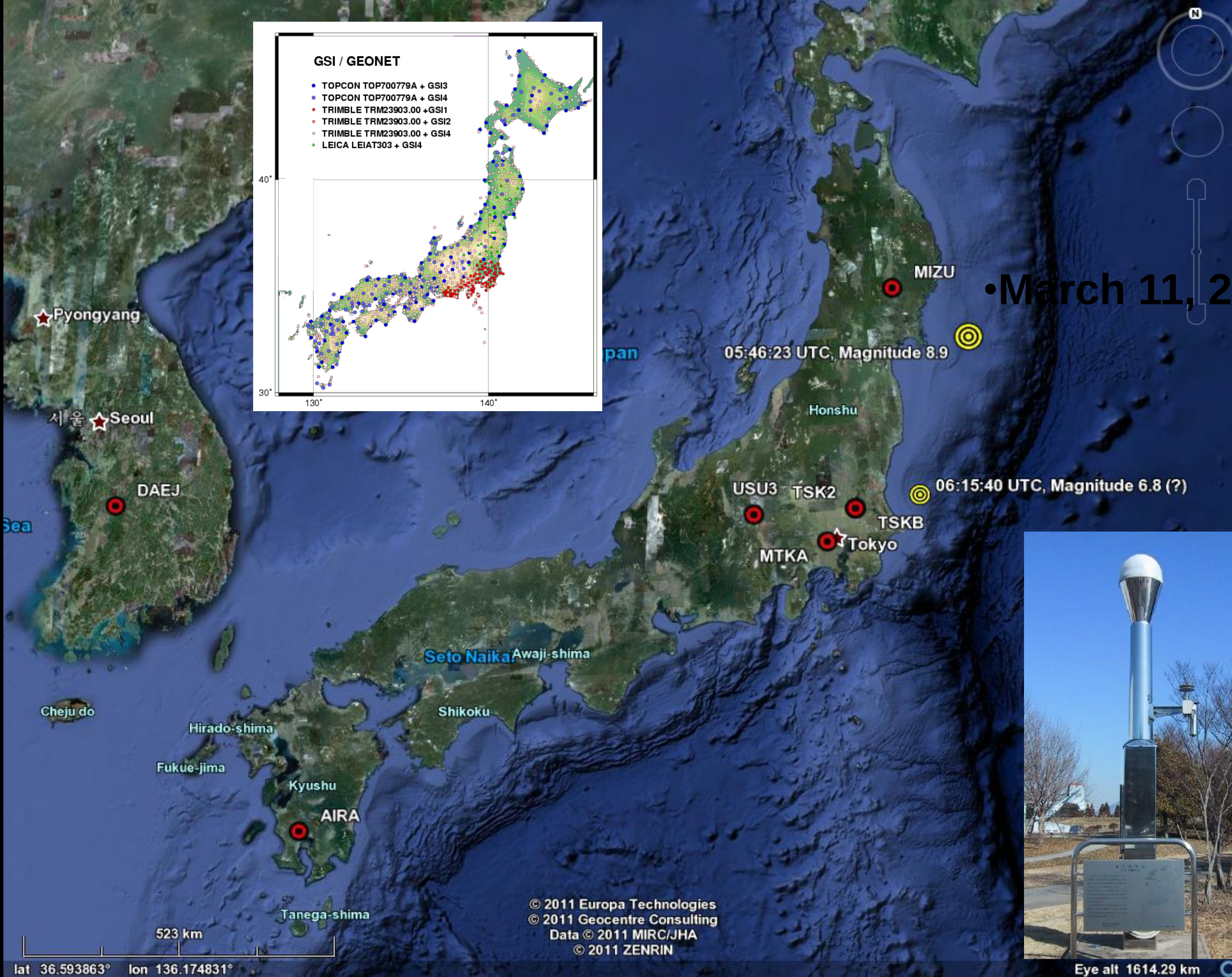
nehrp national earthquake hazards reduction program

San Andreas Fault lifeline crossings

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

- March 11, 20



MIZU
05:46:23 UTC, Magnitude 8.9
06:15:40 UTC, Magnitude 6.8 (?)
USU3
TSK2
TSKB
Tokyo
MTKA
Honshu
pan
Pyongyang
서 울
Seoul
DAEJ
Sea
Seto Naikai
Awaji-shima
Shikoku
Cheju do
Hirado-shima
Fukue-jima
Kyushu
AIRA
Tanega-shima
523 km
© 2011 Europa Technologies
© 2011 Geocentre Consulting
Data © 2011 MIRC/JHA
© 2011 ZENRIN
lat 36.593863° lon 136.174831°
Eye alt 1614.29 km
N
GSI / GEONET
TOPCON TOP700779A + GSI3
TOPCON TOP700779A + GSI4
TRIMBLE TRM23903.00 +GSI1
TRIMBLE TRM23903.00 + GSI2
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LEICA LEIAT303 + GSI4
40˚
30˚
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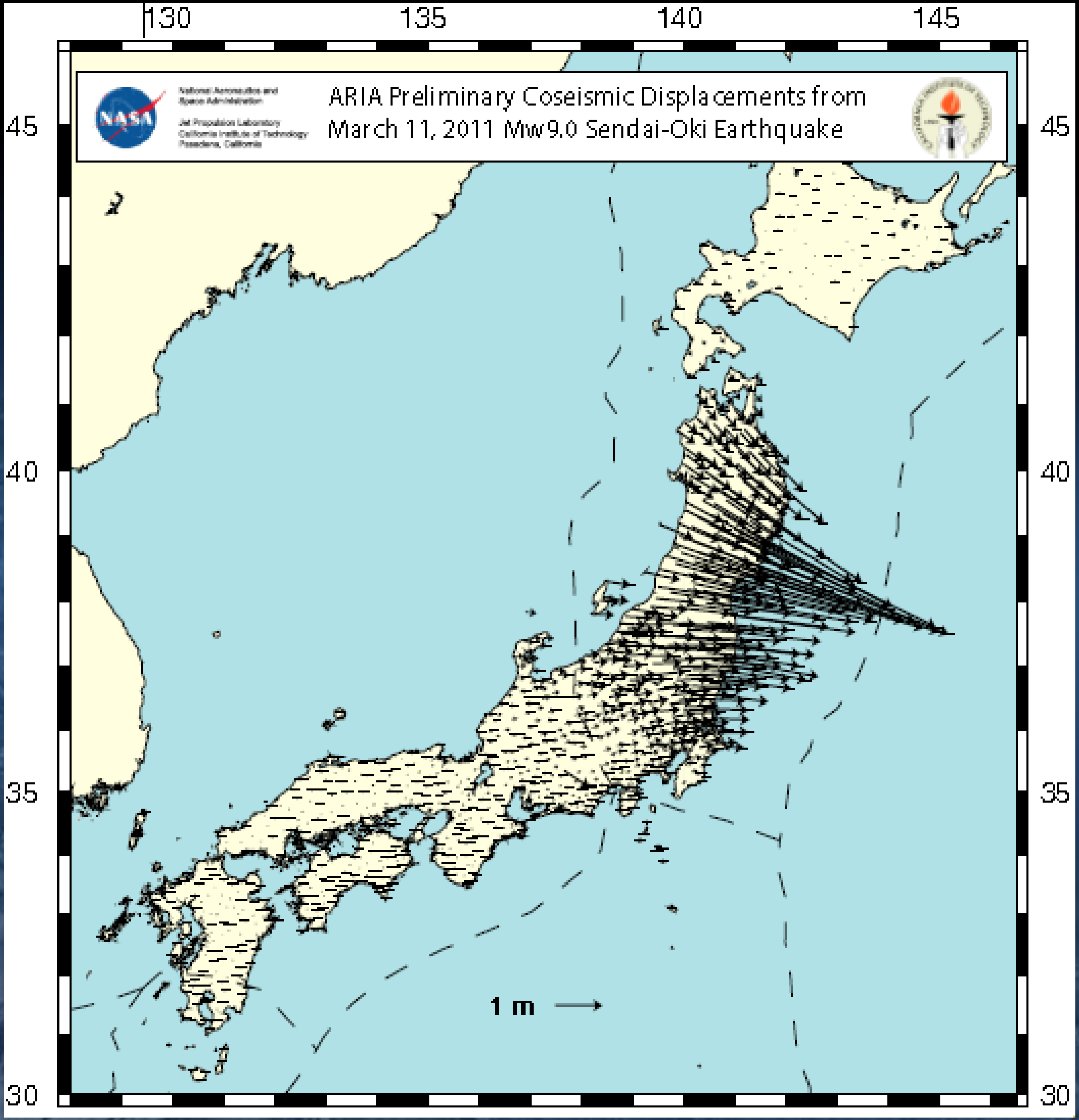
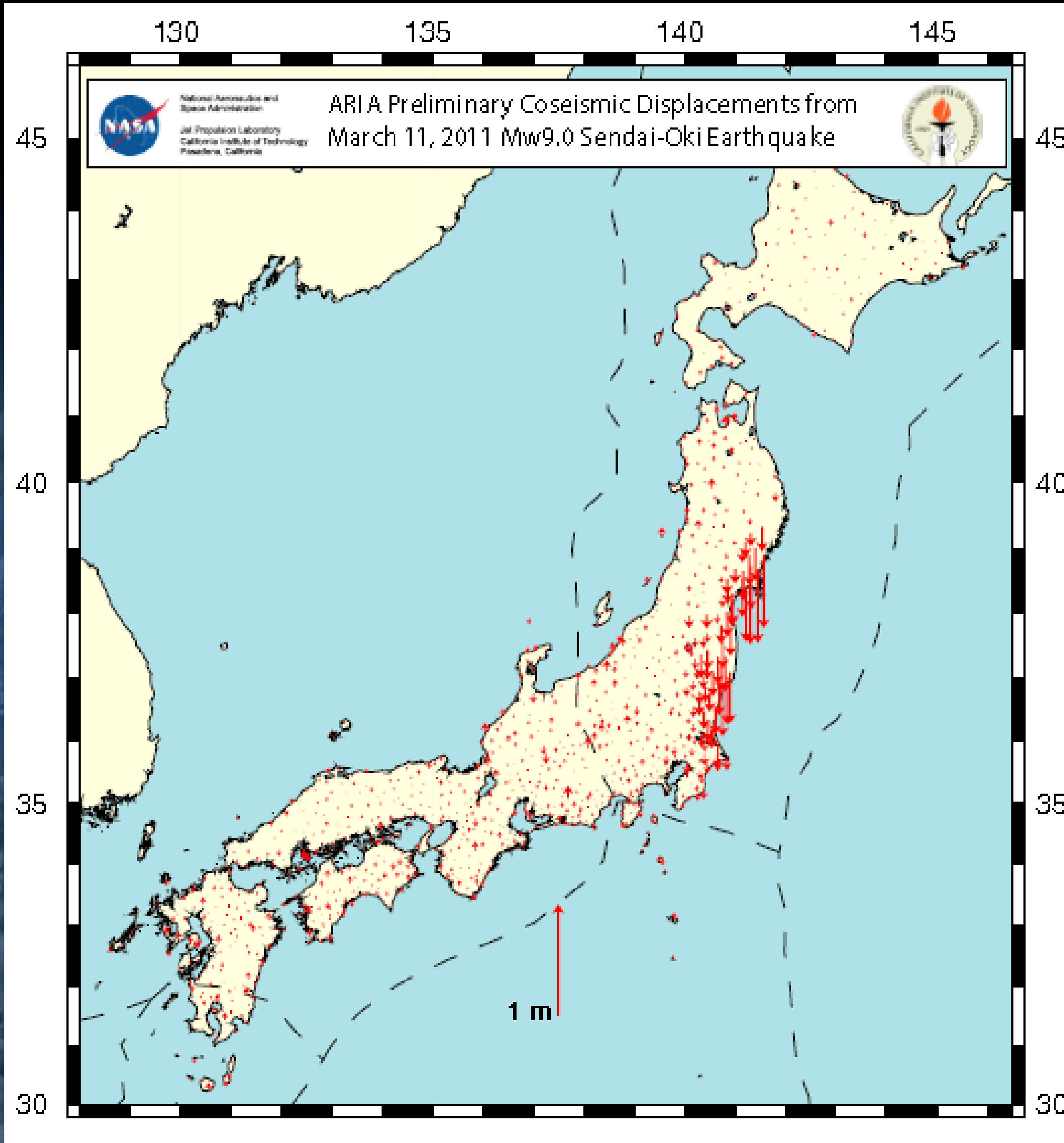
140˚



Horizontal Displacements

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

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



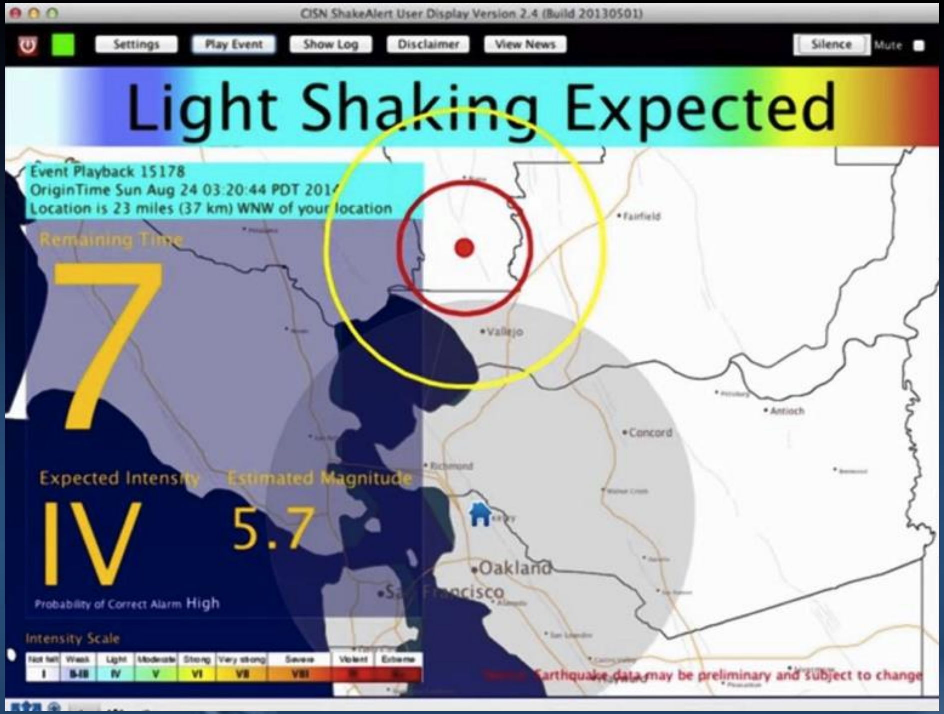
Vertical Displacements

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

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

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.

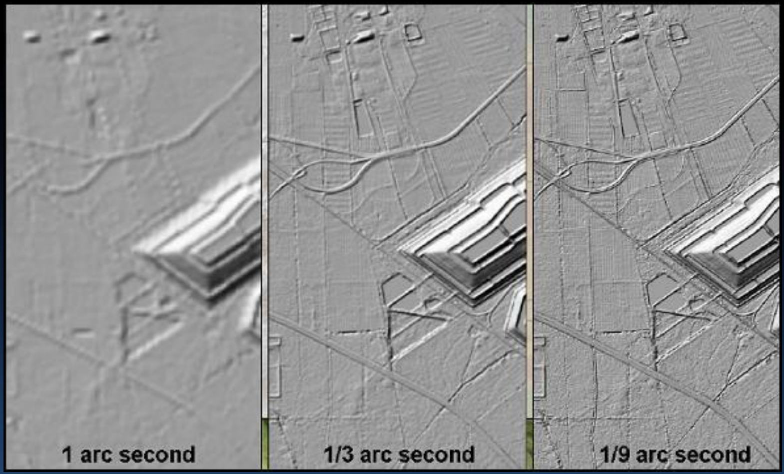


- Potential to provide additional situational awareness for critical infrastructure operators.

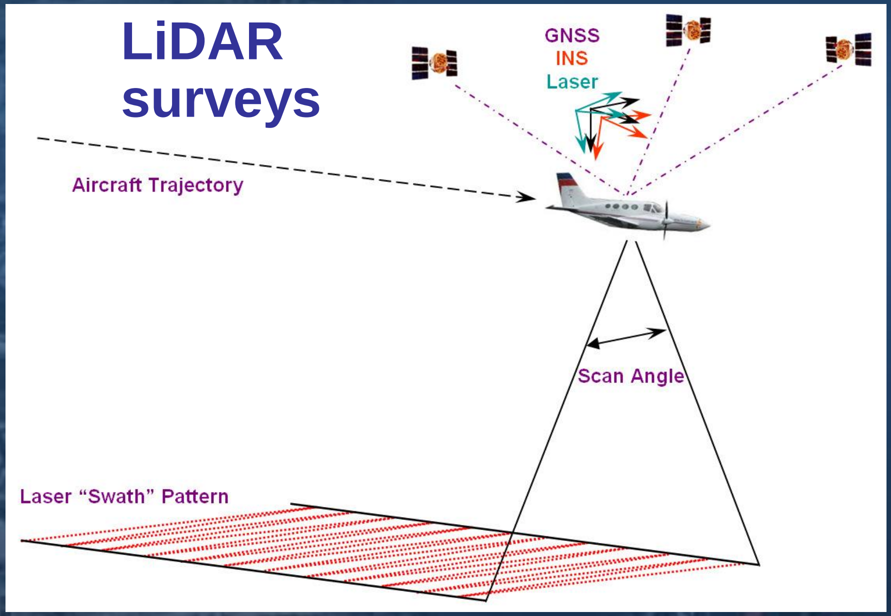
Image Source: UC Berkeley

GPS is 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**.



High accuracy terrain elevation data is replacing older, lower resolution data



LiDAR (Light Detection and Ranging) - a remote sensing technology

High resolution orthorectified imagery

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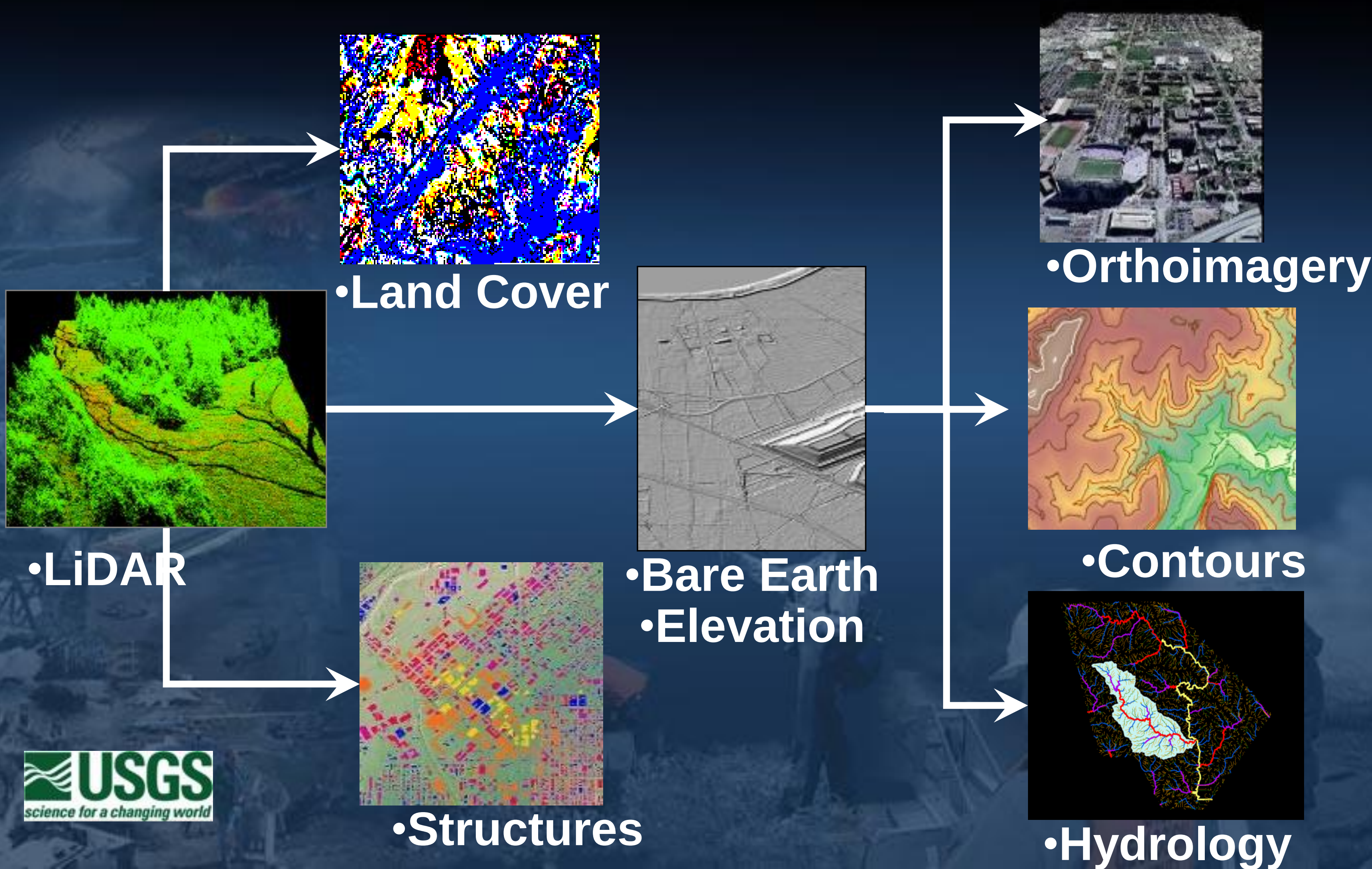
Accurate LiDAR mapping is highly relevant to several data layers of The National Map



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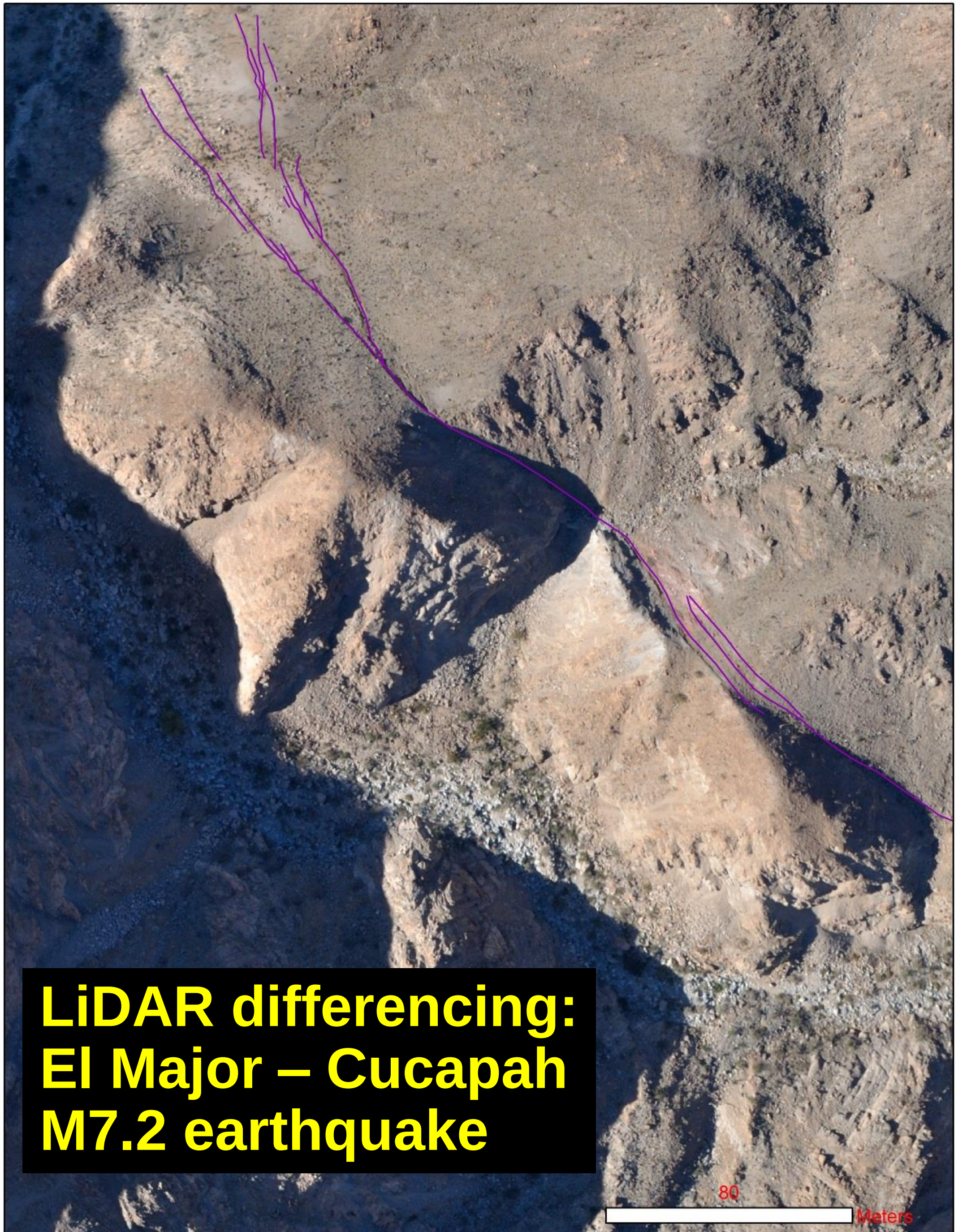
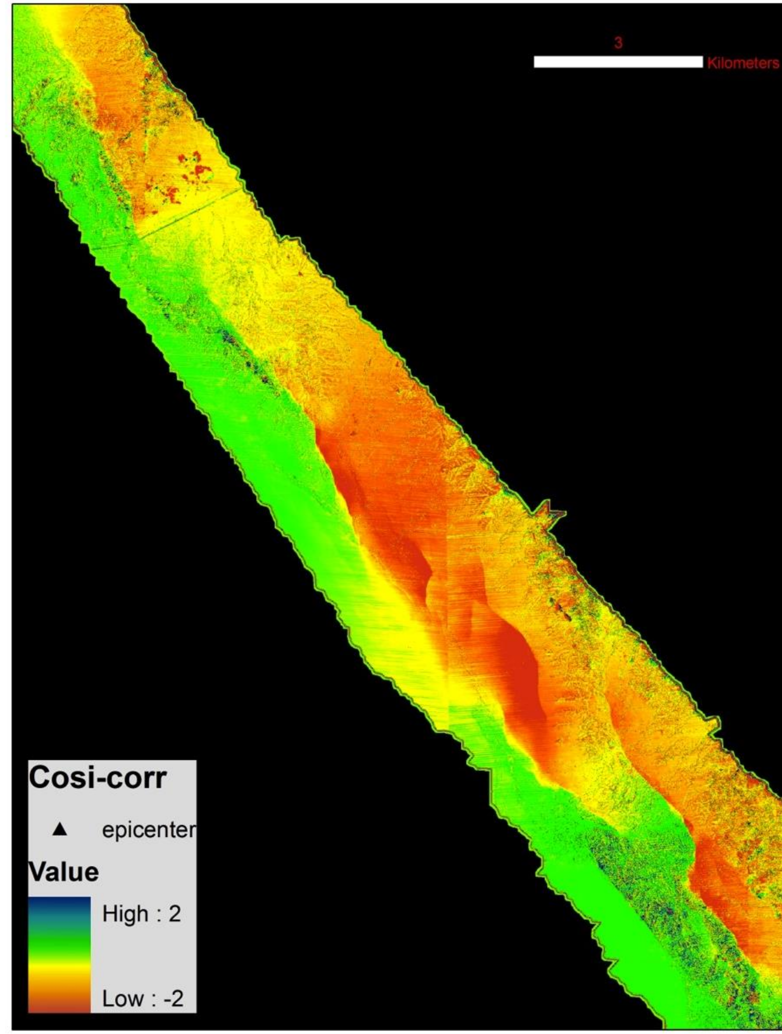


LiDAR differencing: El Major – Cucapah M7.2 earthquake



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

- LiDAR
- 3D stereo

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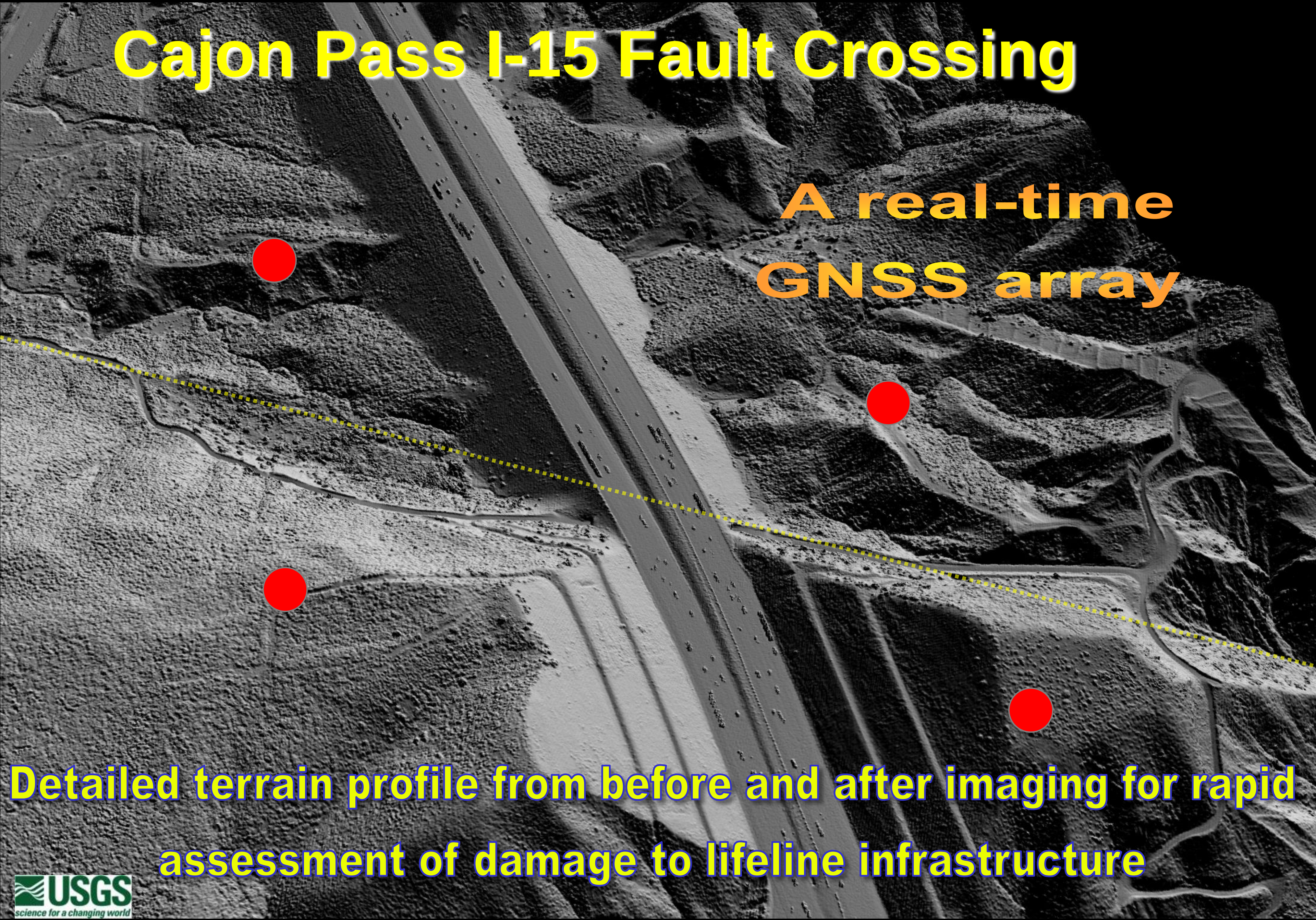
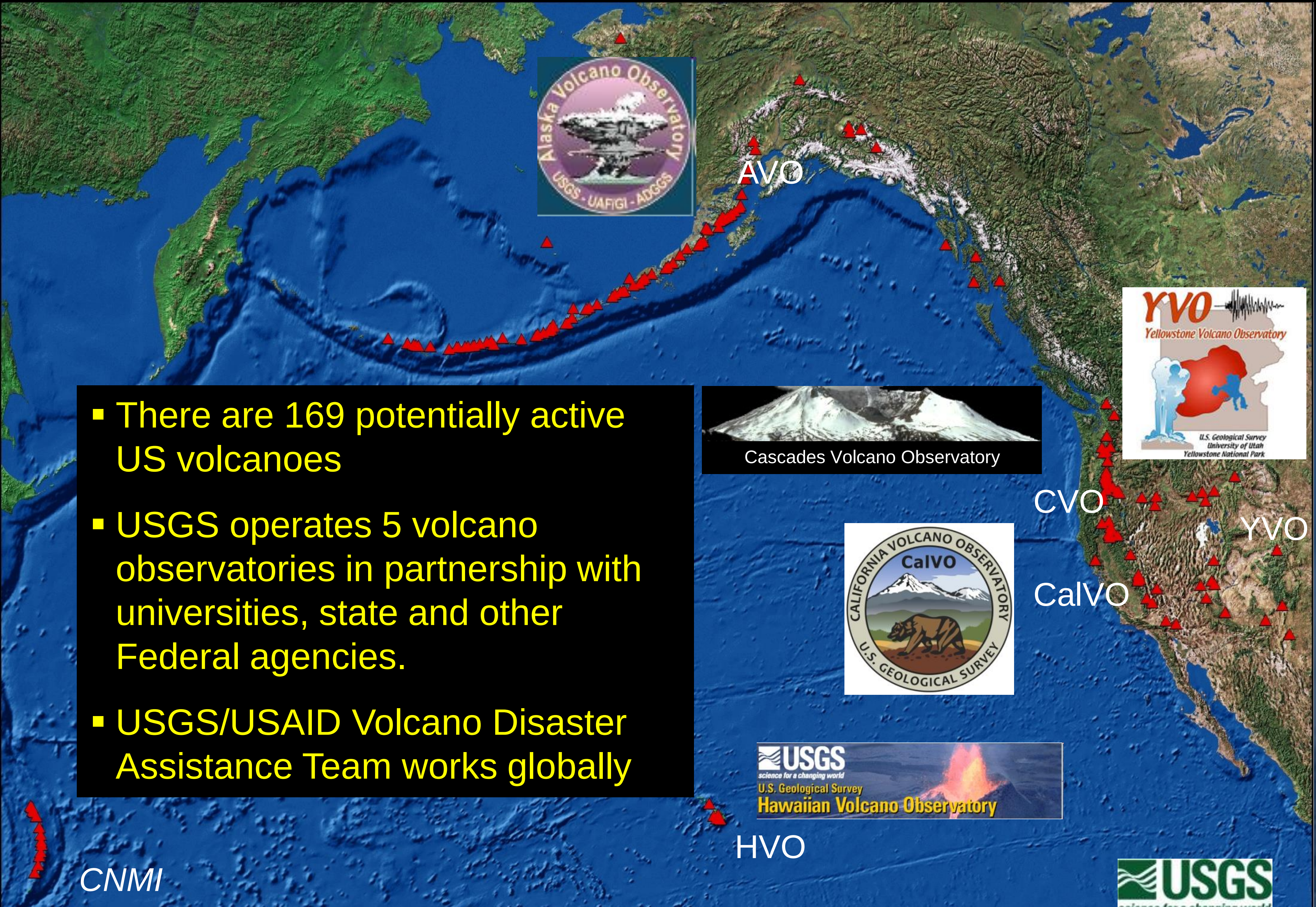
Cajon Pass I-15 Fault Crossing



Detailed terrain profile from before and after imaging for rapid assessment of damage to lifeline infrastructure

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



Monitoring Volcano Ground Deformation

Changes at the Surface Tell us about the Subsurface

Most volcano deformation can only be detected and measured with precise surveying techniques

GPS/GNSS

Precision Monitoring at individual ground locations

Tilt

Measuring tiny changes in the slope angle or "tilt" of the ground

InSAR

Mapping ground deformation of large areas using radar images from Earth-orbiting satellites.

EDM

Measuring the distance between benchmarks placed on a volcano tens to thousands of meters apart

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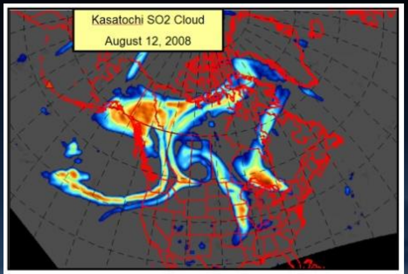
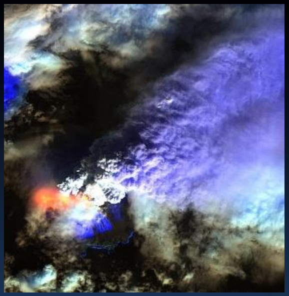
Volcano observatories combine an array of real time data streams to interpret behavior and forecast eruptions

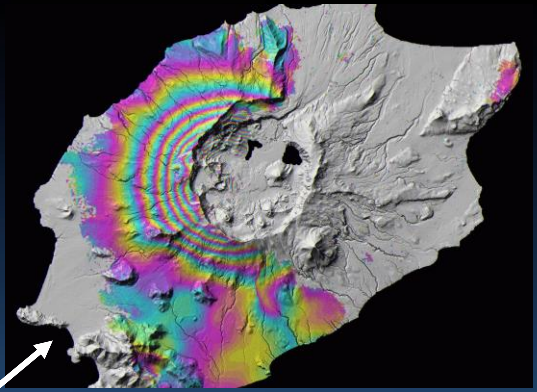


Gas cloud from satellite UV sensor

AVO operations room

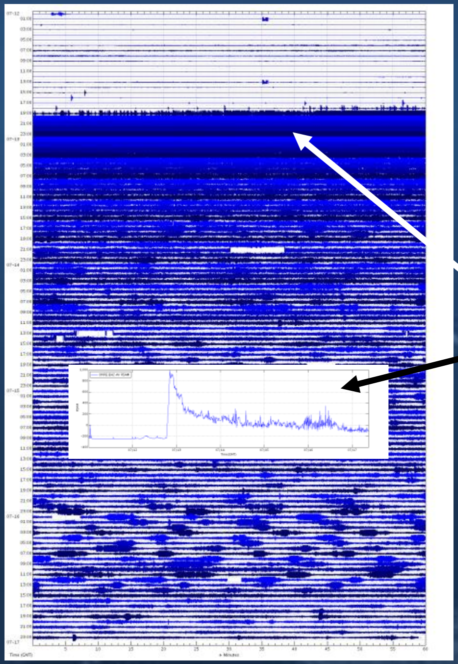


Satellite surveillance for hotspots and ash

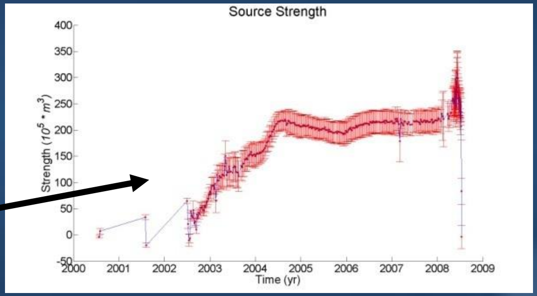


Volcano deformation from radar satellites

AVO field installation

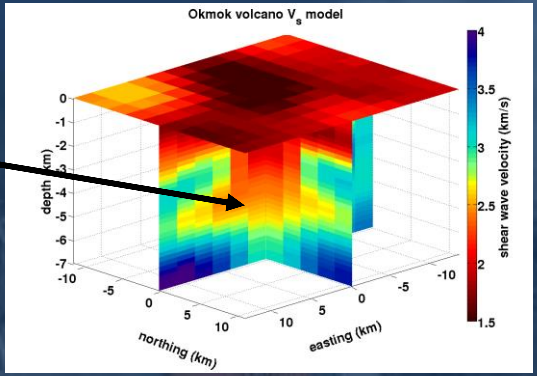


Volcano deformation from GPS



Eruption onset from seismic network

Magma chamber location from seismic tomography



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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)

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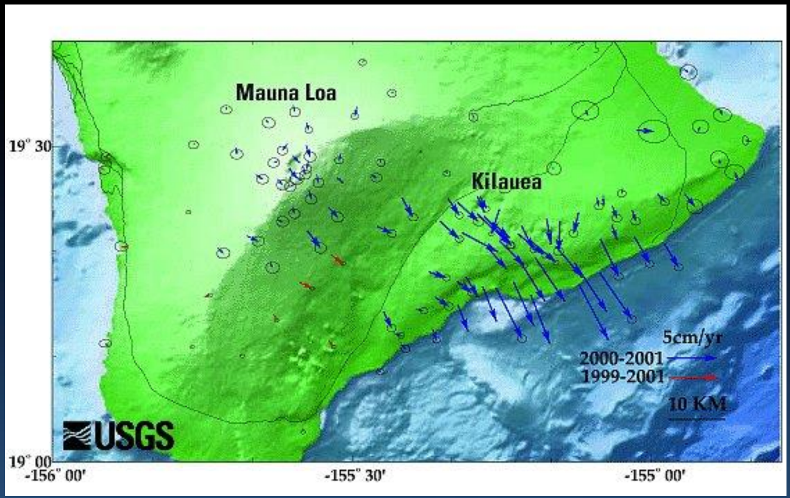
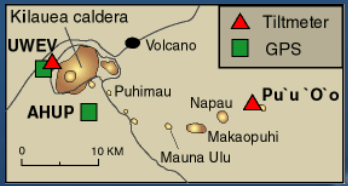
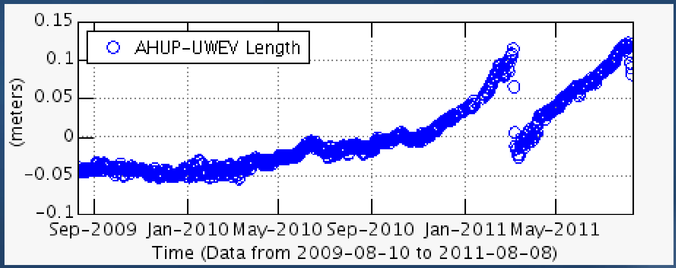
USGS uses precise GPS for eruption monitoring

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







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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

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

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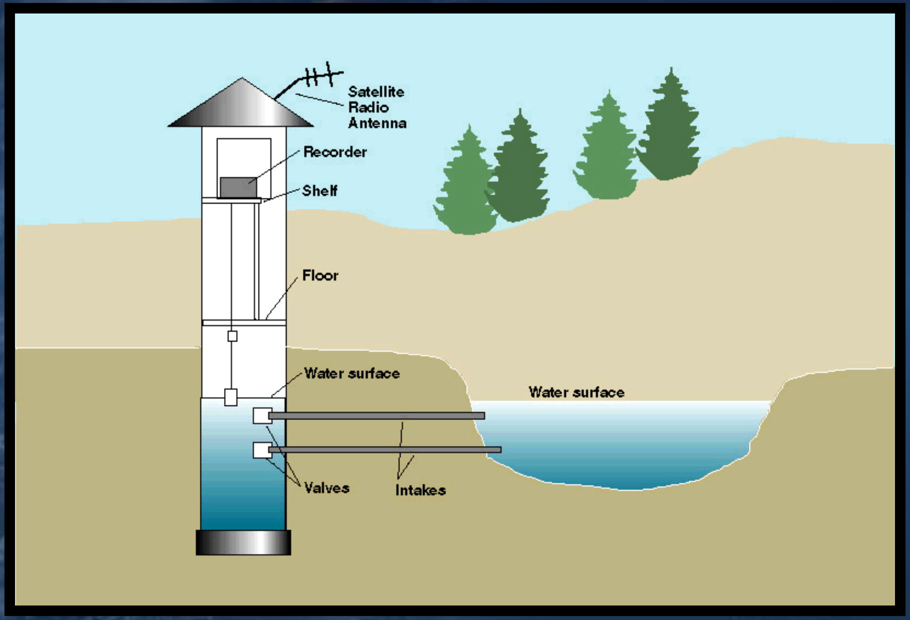
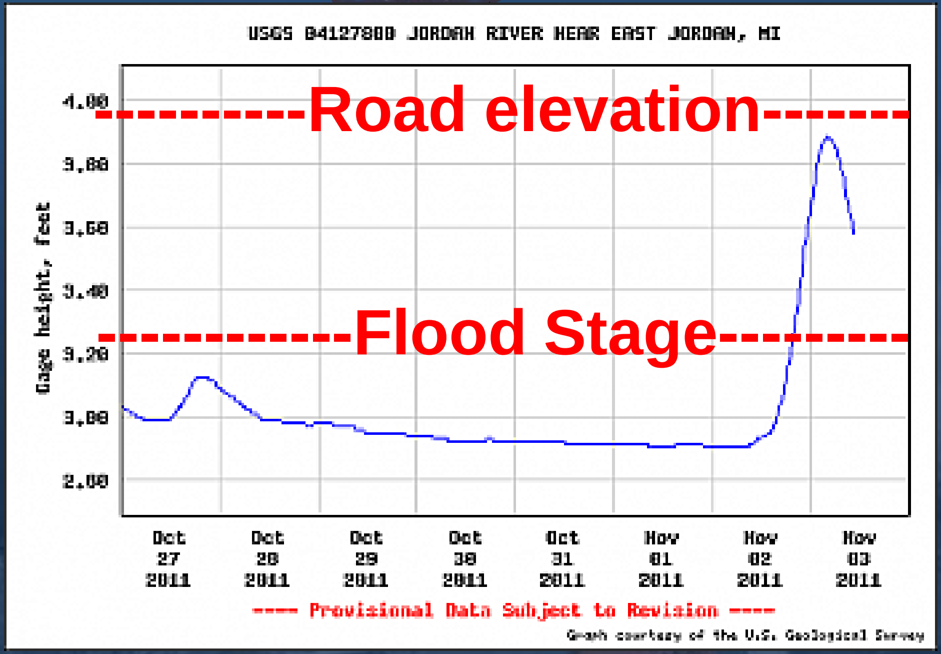
USGS WaterAlert

Text message or e-mail customized alerts





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

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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).

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Questions?