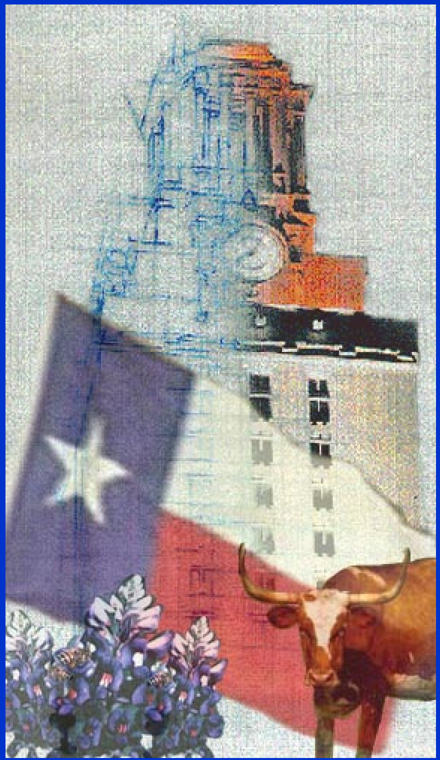
Emerging Technologies for Event Reconnaissance: Current and Future Opportunities



Prof. Ellen M. Rathje
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University of Texas at Austin

GEER Workshop
18-19 May 2009

Outline

- Opportunities
  - Remote sensing
    - High-resolution optical imagery
    - Synthetic Aperture Radar (SAR)
    - LIDAR- airborne and terrestrial
  - Data fusion
    - Real-time vs. post-reconnaissance
- A recent experience
  - 2008 Wenchuan, China earthquake
- Remaining Challenges

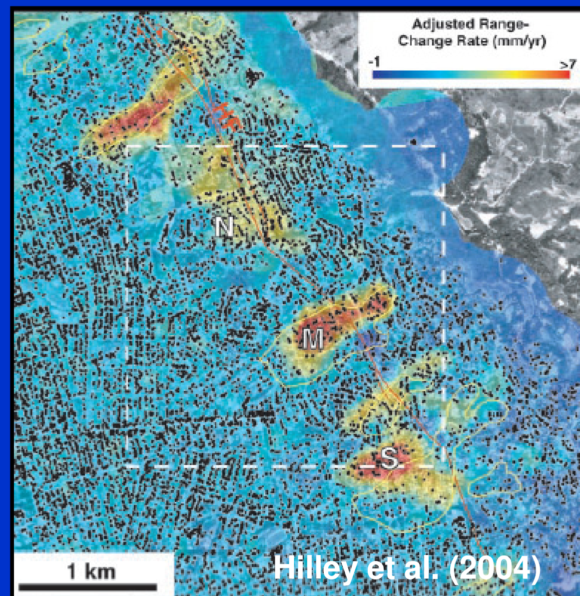
Remote Sensing

- Acquiring data using sensors <u>not</u> in direct physical contact with the area being studied

Optical satellite imagery

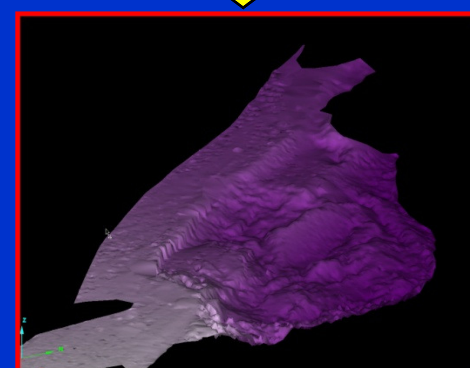
Resolution as high as 0.4 m
Identification of damage
Cloud cover an issue

SAR



Resolution as high as 1 m
Identification of damage
Measure movements
Cloud cover <u>not</u> an issue

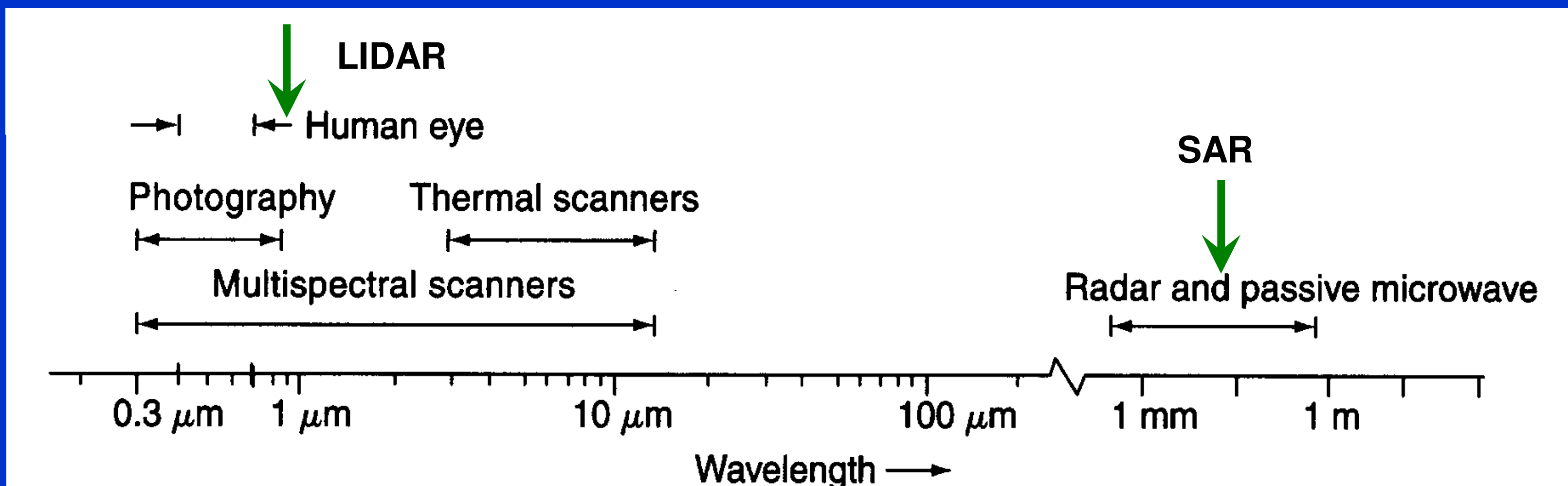
LIDAR



Kayen et al. (2006)

Remote Sensing Data

- Collection of digital data within distinct bands of electromagnetic spectrum



from Lillesand et al. (2004)

LANDSAT-7 — 8 bands, 15 - 30 m res

SPOT- 5 — 5 bands, 2.5 - 20 m res

IKONOS, KOMPSAT — 5 bands, 1- 4 m res

Quickbird — 5 bands, 0.6 - 2.4 m res

GeoEye-1 — 5 bands, 0.4 – 1.6 m res

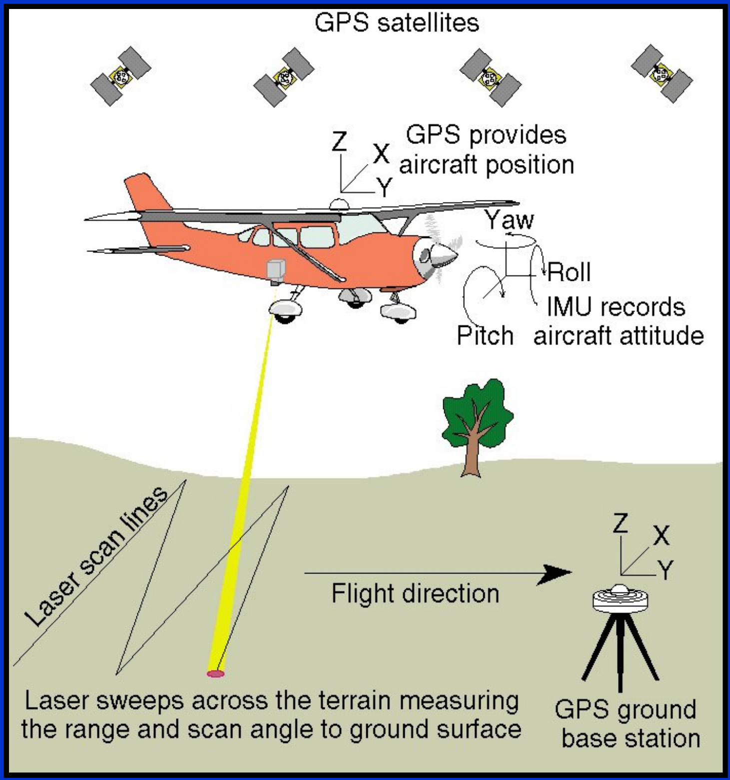
SAR

Envisat	C band (4-8 cm) 30 m res
TerraSAR-X	X band (2.4 - 4 cm) 1 – 16 m res
COSMO-SkyMed	X band (2.4 – 4 cm) 1 – 30 m res

Airborne LIDAR

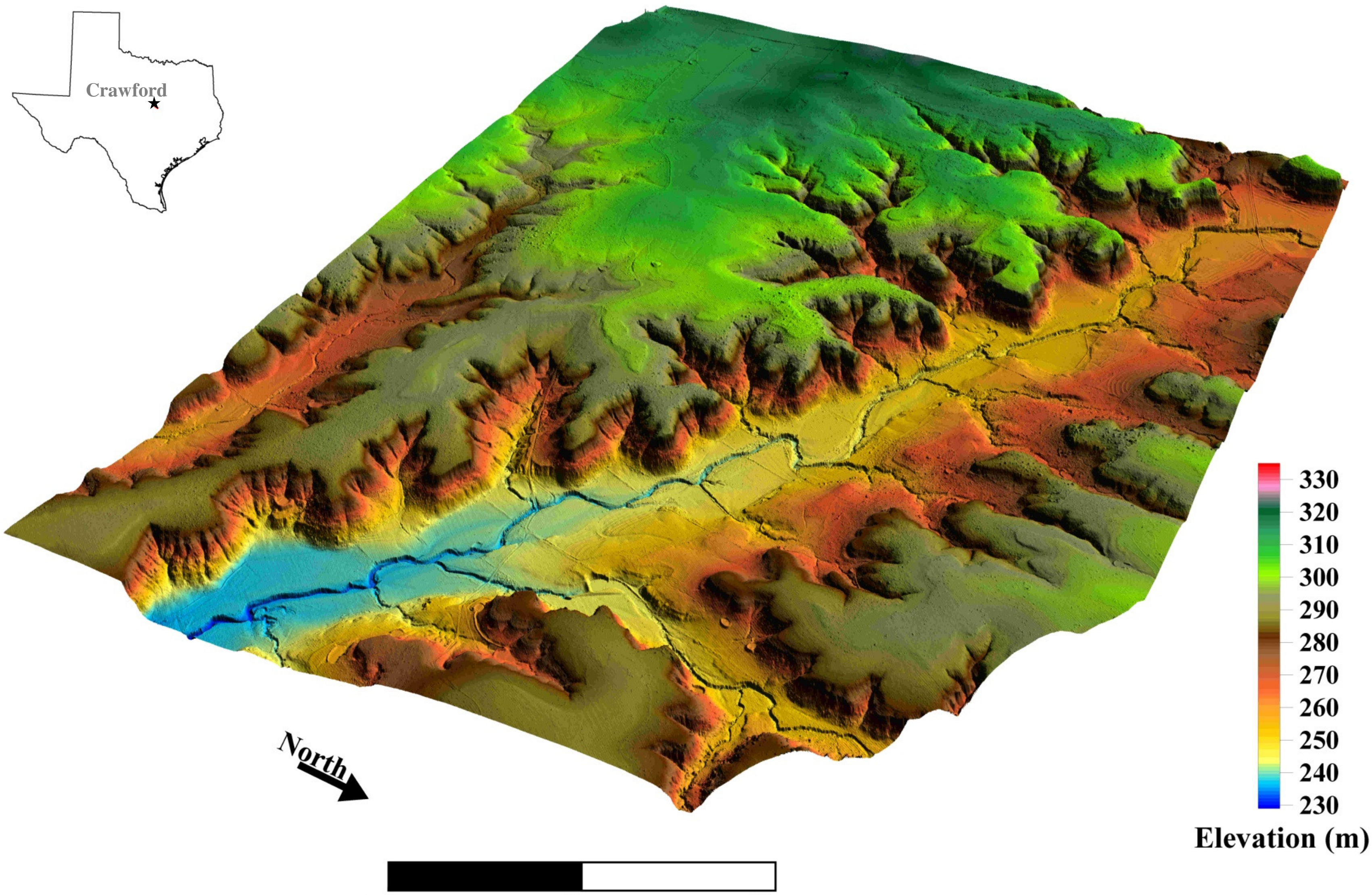
- **The Airborne Laser Terrain Mapping (ALTM) system combines the precision of LIDAR (Light Detection and Ranging) with the absolute accuracy of GPS to measure topography.**

- A powerful *laser* pulses thousands of times per second, *scanning* across the Earth beneath the survey aircraft.
- The position of the aircraft is estimated using GPS equipment in the aircraft and at ground control stations.
- An Inertial Measurement Unit (IMU) is used to remove the effects of aircraft attitude
- All three data streams (laser ranges, IMU information, and GPS positions) are merged and processed to generate a series of topographic points.
- *Accuracy* < 10 cm
- *First and last return* of the laser is recorded
- New development: full waveform digitizer



Slide from Roberto Gutierrez (UT-CSR)

Comparison of NED, SRTM, Lidar Topography: Coryell Creek, Texas

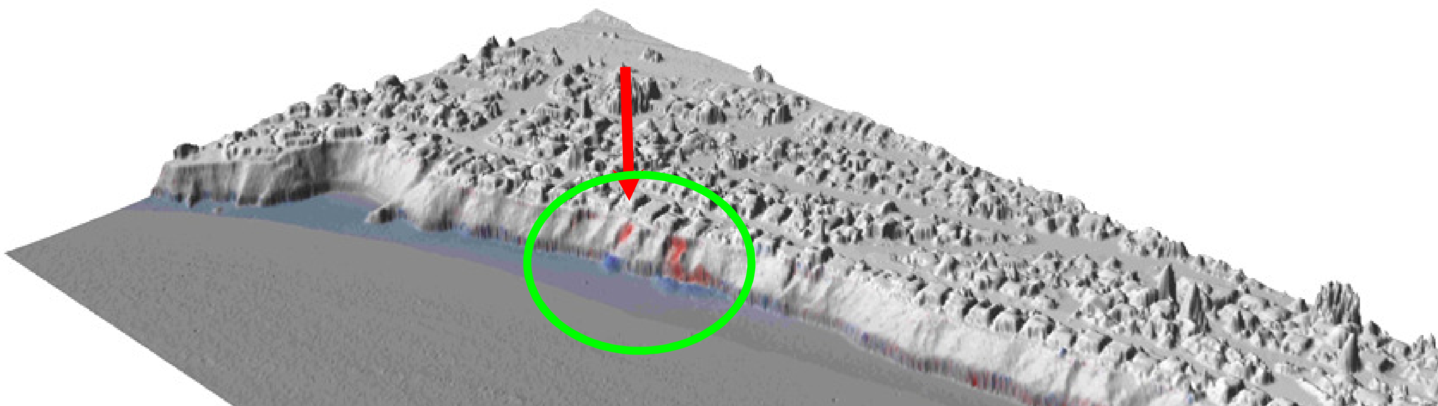


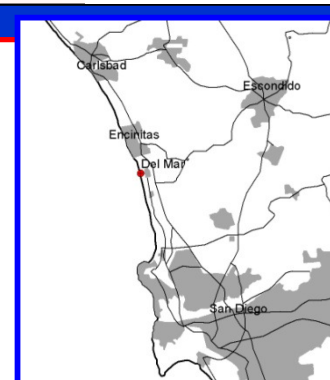
2 m x 2 m Bare Earth-only Lidar DEM
March, 2004

4X Vertical Exaggeration

Slide from Roberto Gutierrez (UT-CSR)

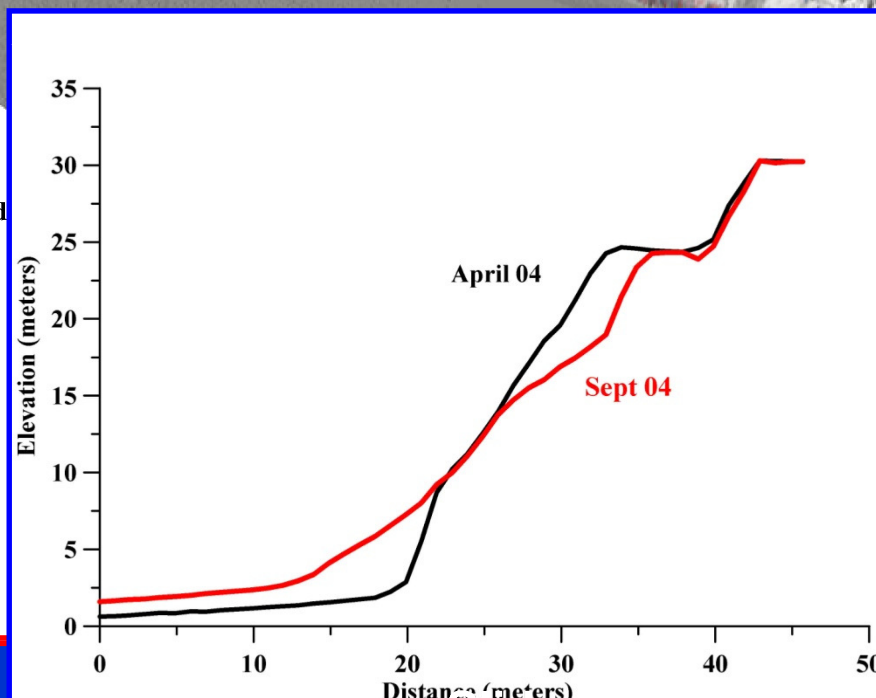
Solana Beach, California





Solana Beach
Del Mar, California
Airborne Lidar digital elevation mod
Elevation is meters, NAVD88

Red = erosion
Blue= accretion



Slide from Roberto Gutierrez (UT-CSR)

Ground-based LIDAR

Riegl z210i
Rotating LASER Mapper:

- **~400m Range, ~800m area**
- Accuracy~1.0 cm
- Targets: 7.2M in 15 minutes
- Scan window: 80° by 336°

USGS-Geologic Division System (R. Kayen)

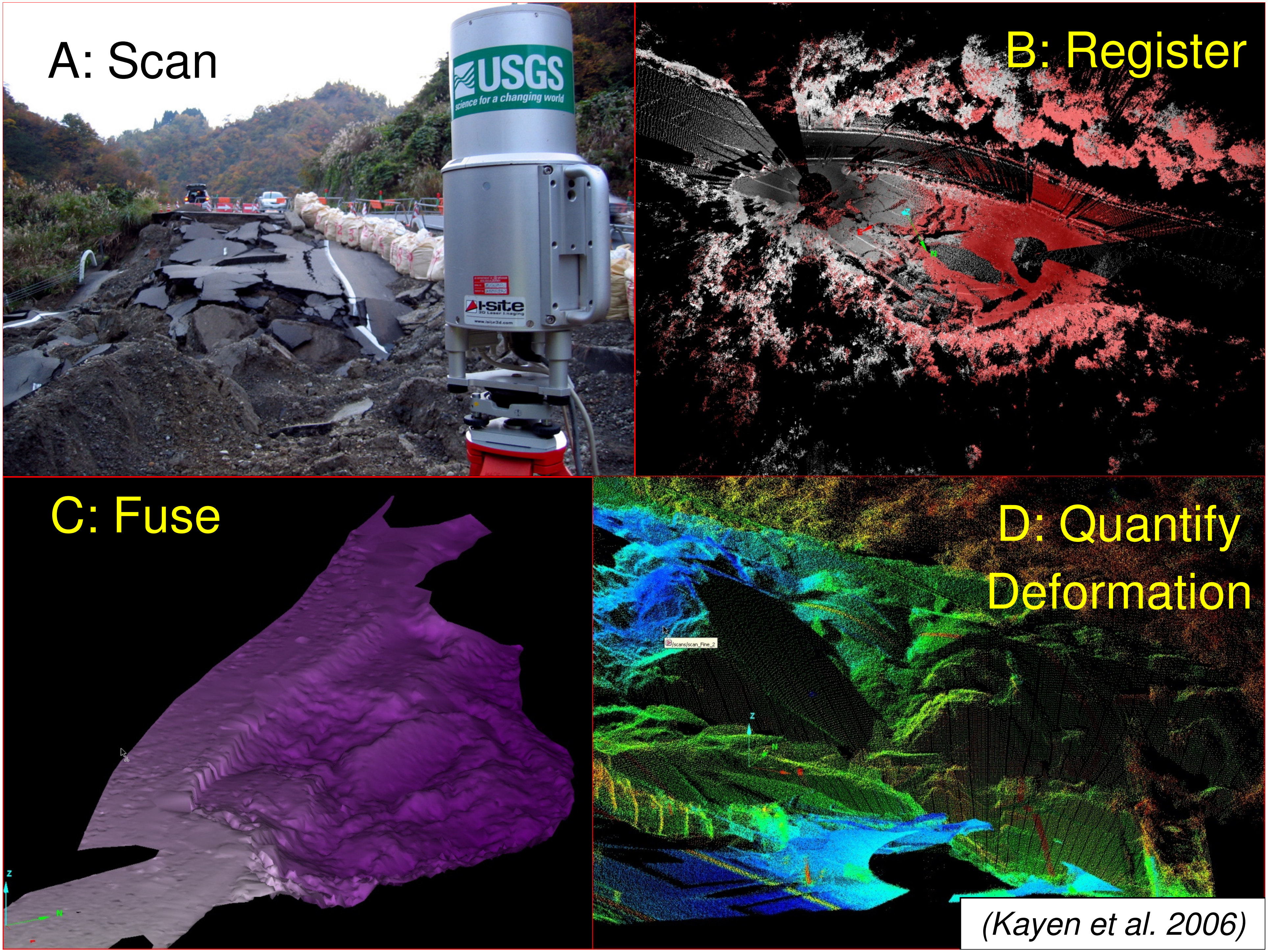
OpTech ILRIS-3D
Fixed window LASER Mapper

- ~ **1.5 km Range**
- Accuracy~0.5 cm
- Targets: 1.8M in 15 minutes
- Fixed window: 40° by 40°

USGS-Water Resources Division System

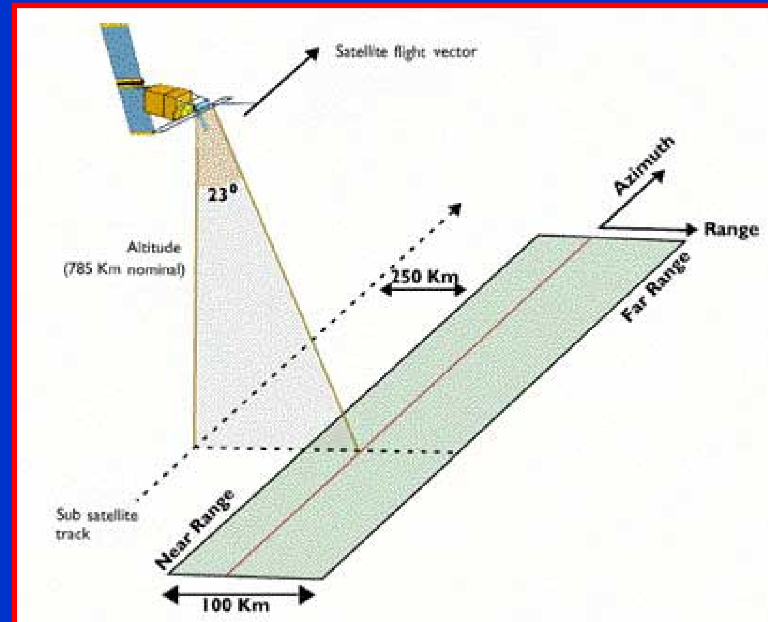
UT Bureau of Economic Geology System

(from R. Kayen, USGS)


A: Scan
USGS
science for a changing world
i-site
B: Register
C: Fuse
D: Quantify
Deformation
(Kayen et al. 2006)

SAR / InSAR

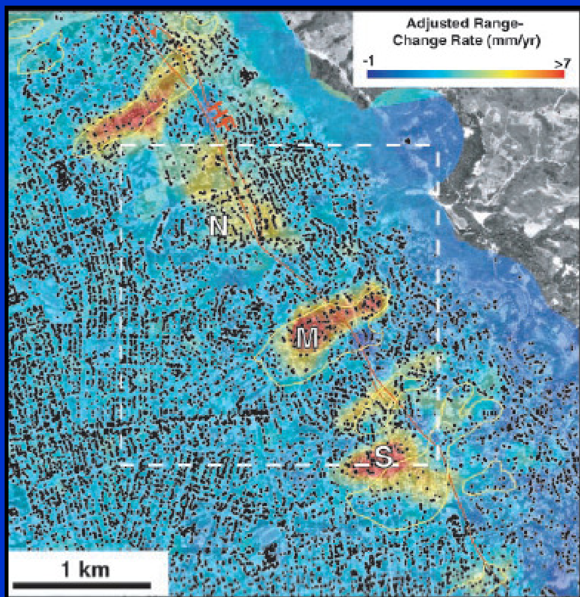
- SAR is an active system that can penetrate clouds, data is difficult to interpret visually
- SAR Interferometry (InSAR): Difference two images to detect surface deformation or topography
- Detect ***cm to mm-level*** defo
- InSAR ground resolution is ***10-90 m***
- New satellites: higher spatial resolution, sensitivity

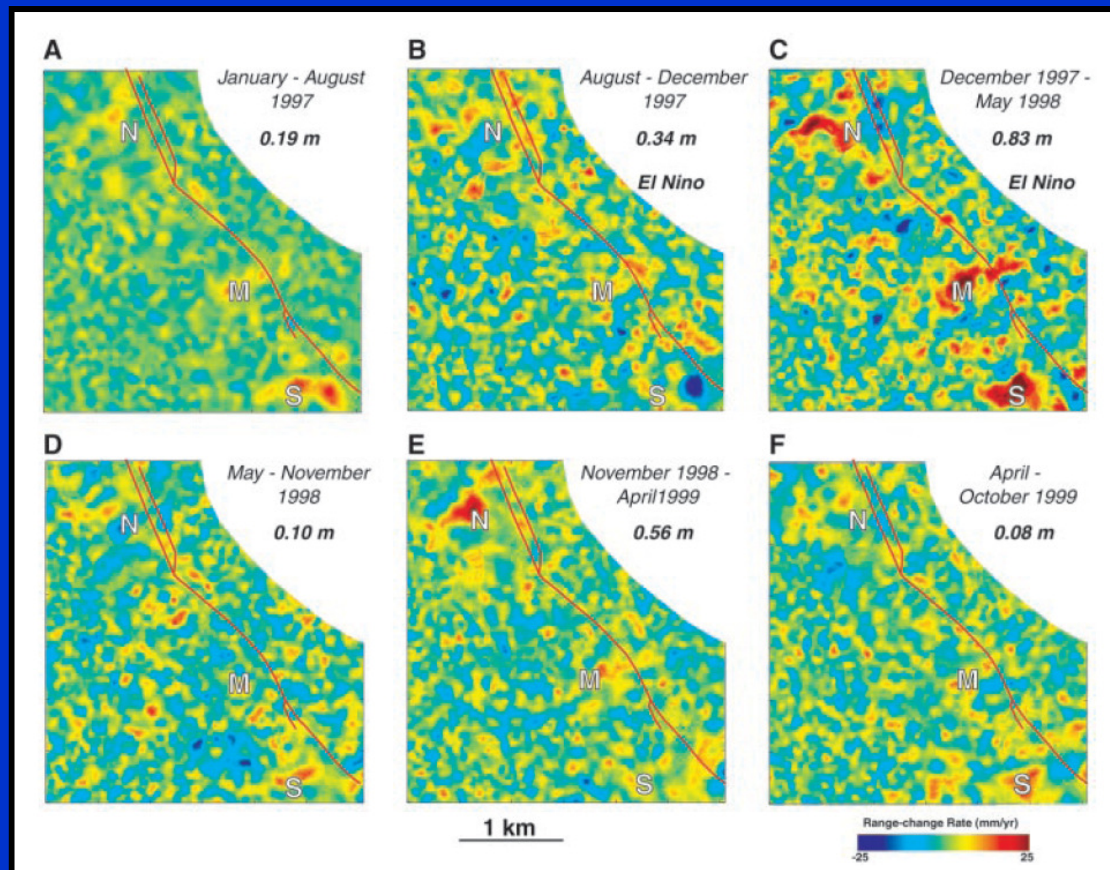


images from earth.esa.int/applications/data_util/SARDOCS/spaceborne/Radar_Courses

Slide from Sean Buckley (UT-CSR)

Landslide Monitoring - Berkeley



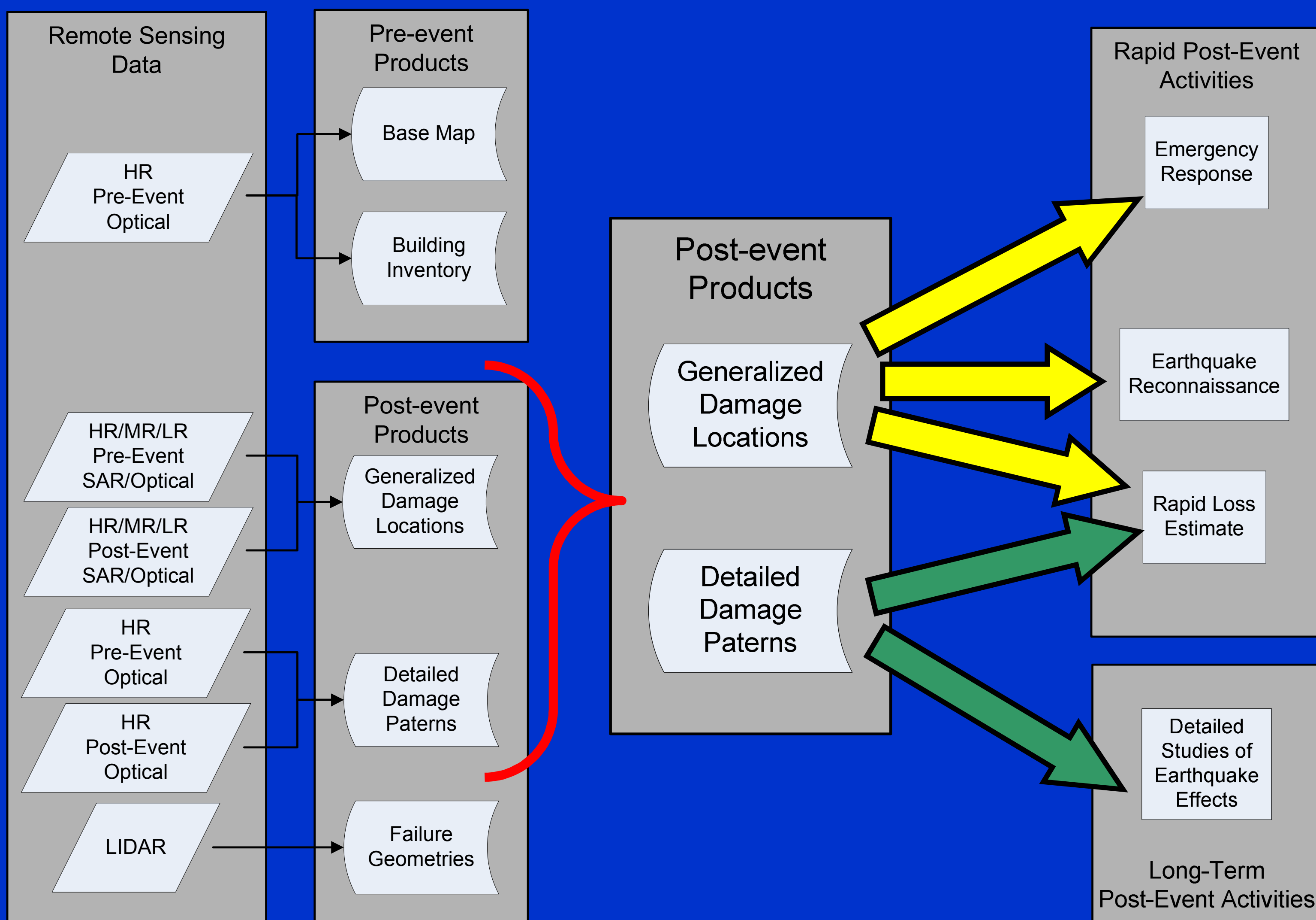


Hilley et al. (2004)

Use in Post-Event Reconnaissance

Remote Sensing Data

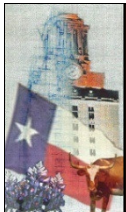
Technical Needs



"Where should we focus our efforts?"

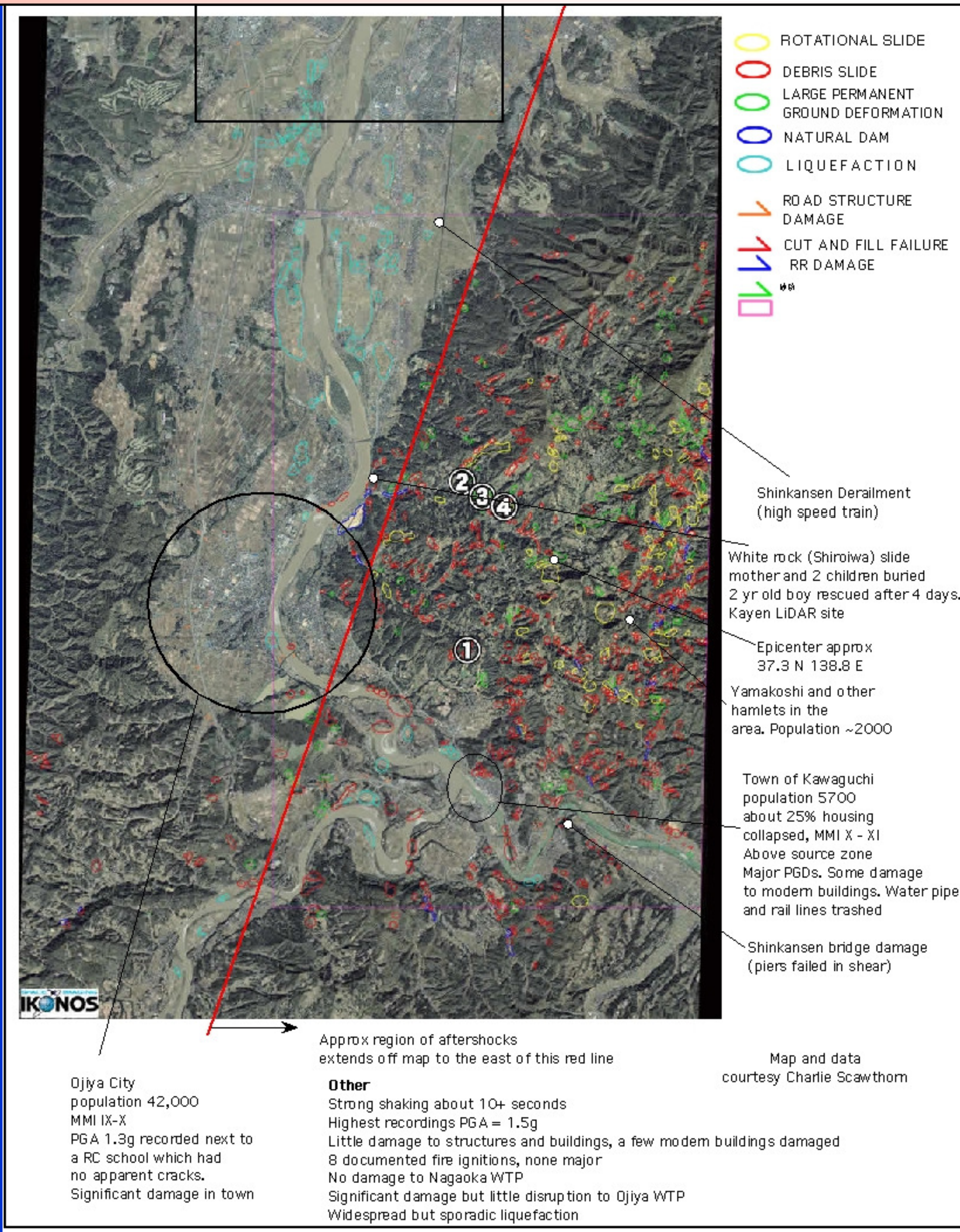
"How much will it cost to recover?"

"What can we learn for next time?"

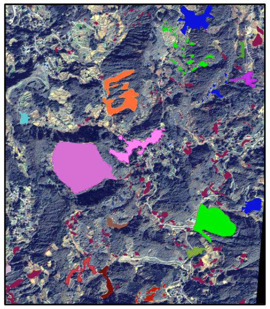


Rapid Response

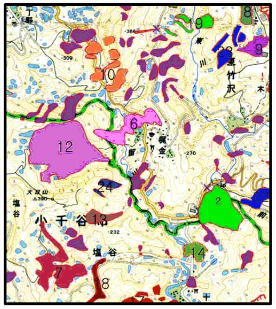
- Reconnaissance of 2004 Niigata-ken Chuetsu Earthquake in Japan
  - Significant landslides
  - Difficult access
- Annotated IKONOS image from C. Scawthorn of Kyoto Univ.
  - Landslides visually identified
  - Liquefaction identified
  - Notes regarding damage, ground motions, previous reconnaissance activities
  - Provided as JPEG



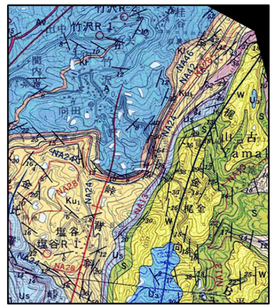
Long-Term Study



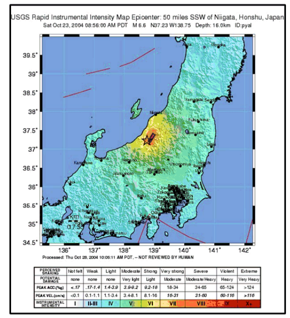
Visual Identification of Landslides



Landslides and Topography

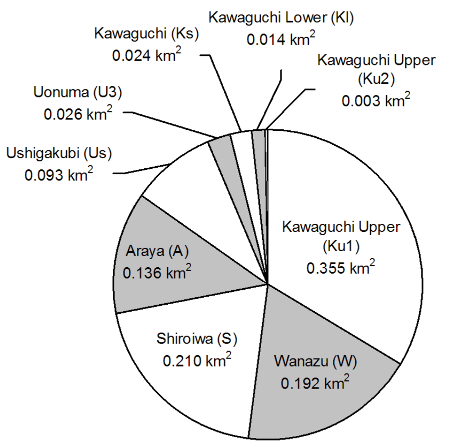


Geologic units

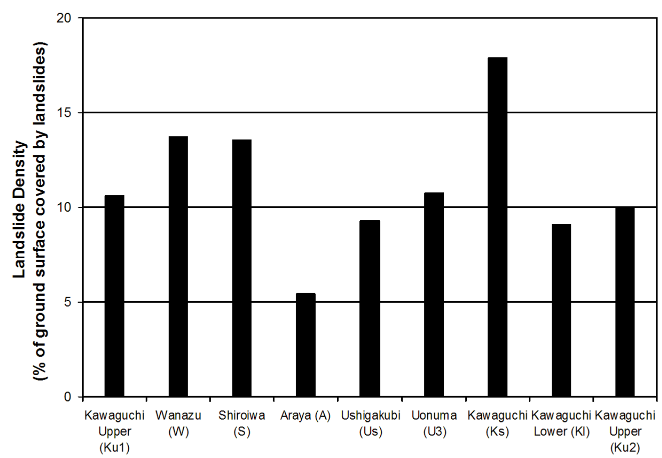


USGS Shakemap

Correlation of Landslide distribution with Geologic Units



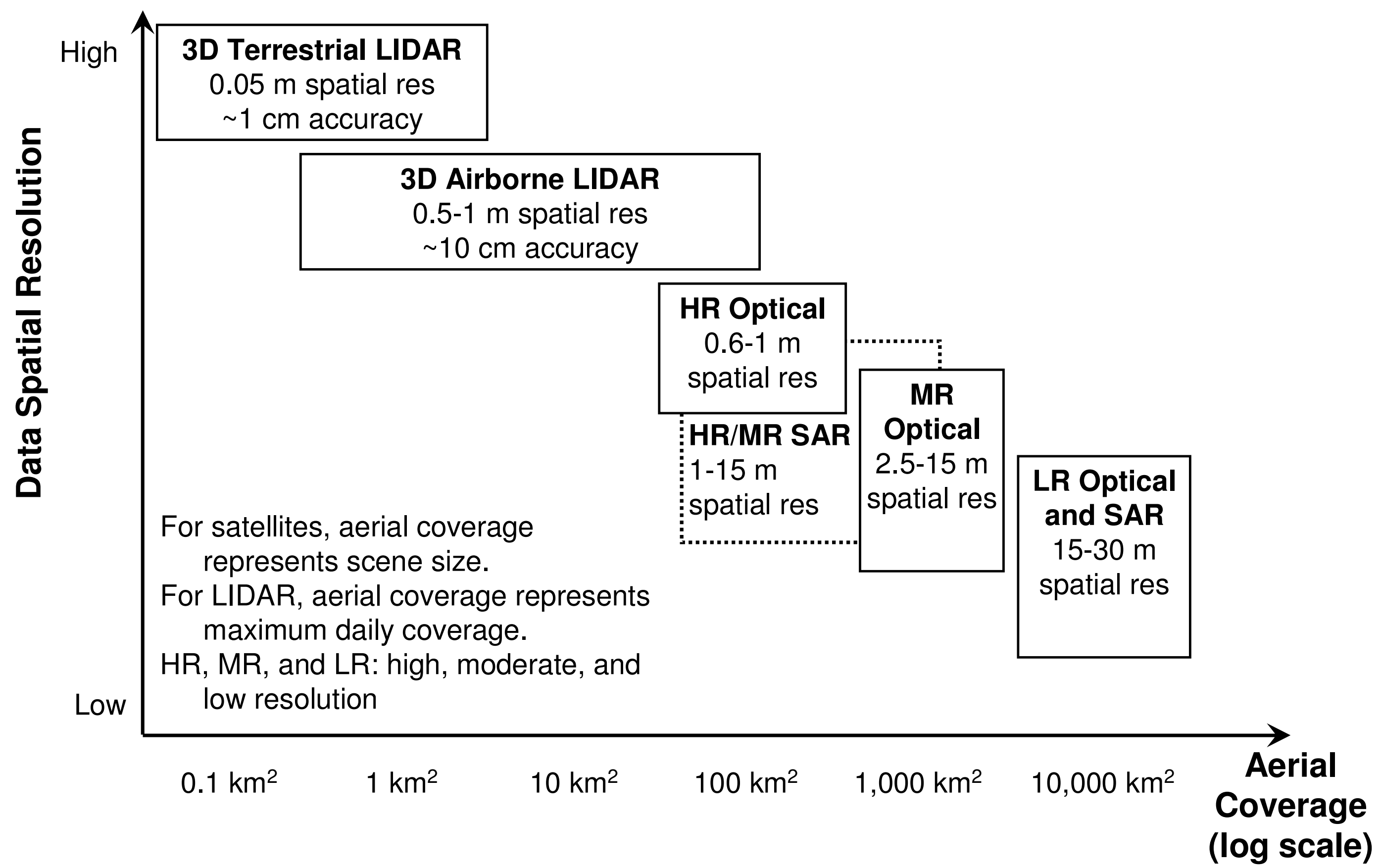
IKONOS Imagery
Total Landslide Area: 1.05 km2



Investigation of landslide distribution from Niigata-ken Chuetsu earthquake

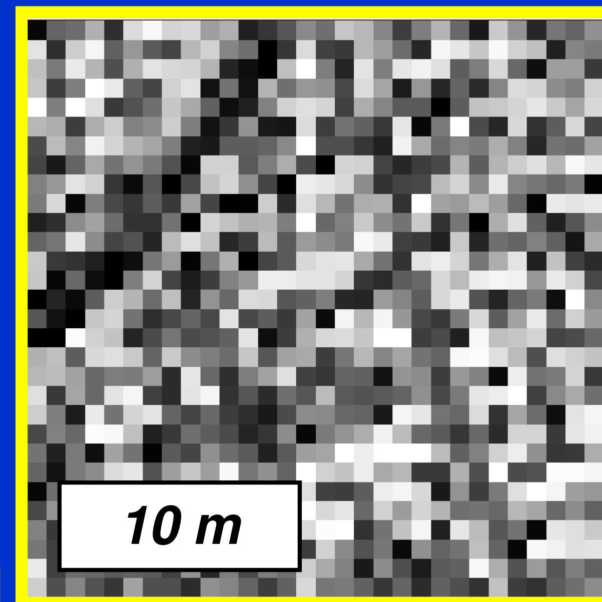
Adapted from Rathje et al. (2006) Soils & Foundations

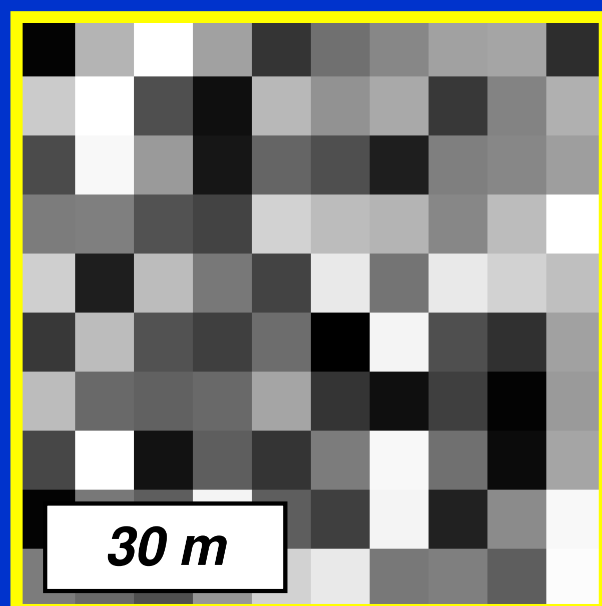
Data Trade-offs



***Rathje and Adams** (2008) Earthquake Spectra*

Spatial Resolutions

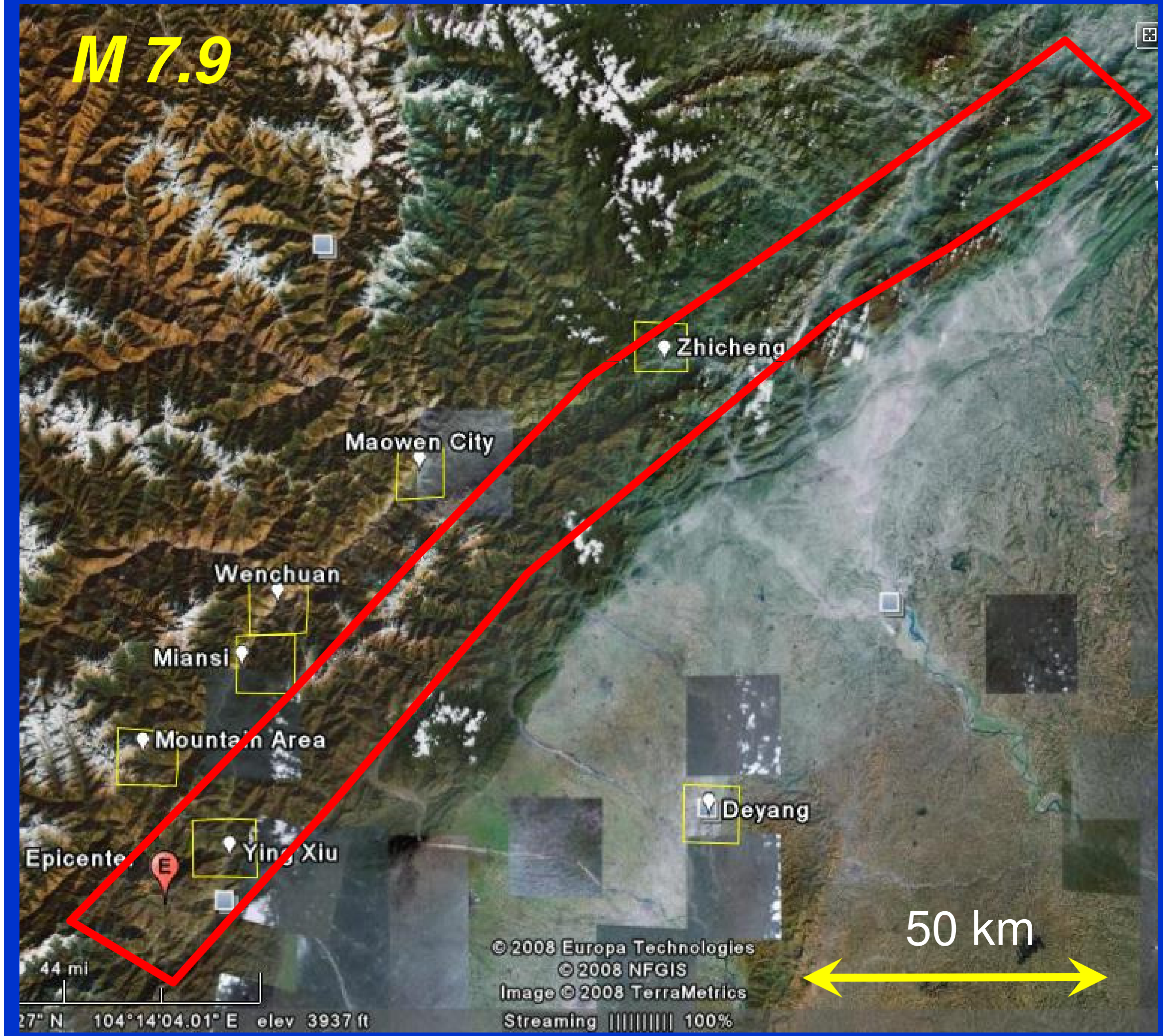




Bam, Iran

Aerial Coverage

Wenchuan (China) Earthquake



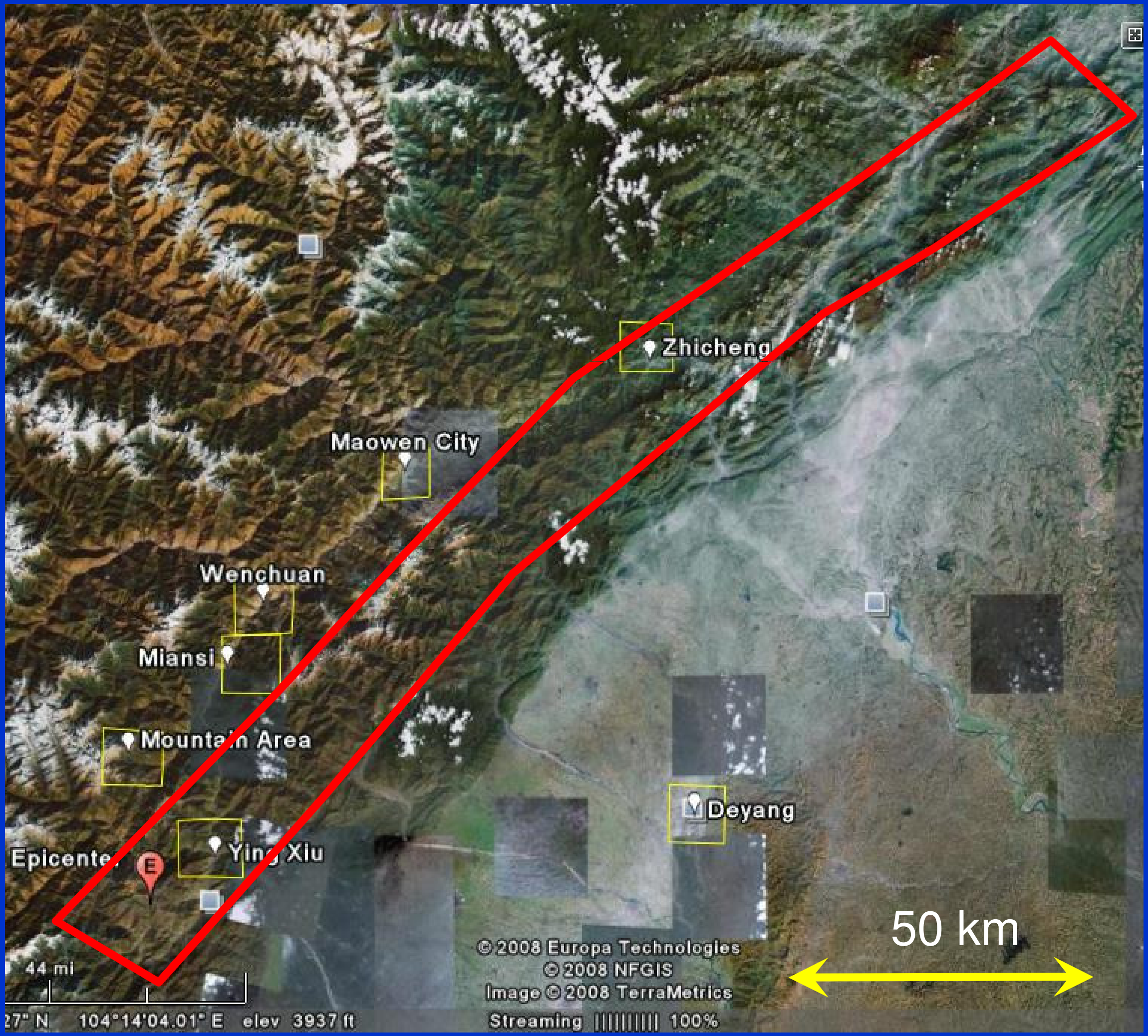
Niigata Earthquake

Data Fusion

- Geo-referenced data and observations from multiple sources can improve interpretations
  - Satellite imagery
  - Geology
  - Topography (Global DEM from SRTM, LIDAR)
  - Digital photographs
  - Fault rupture, ground shaking
- Google Earth provides a platform for data fusion, as well as other GIS programs

2008 Wenchuan Earthquake

M 7.9m, ~ 200 km of fault rupture



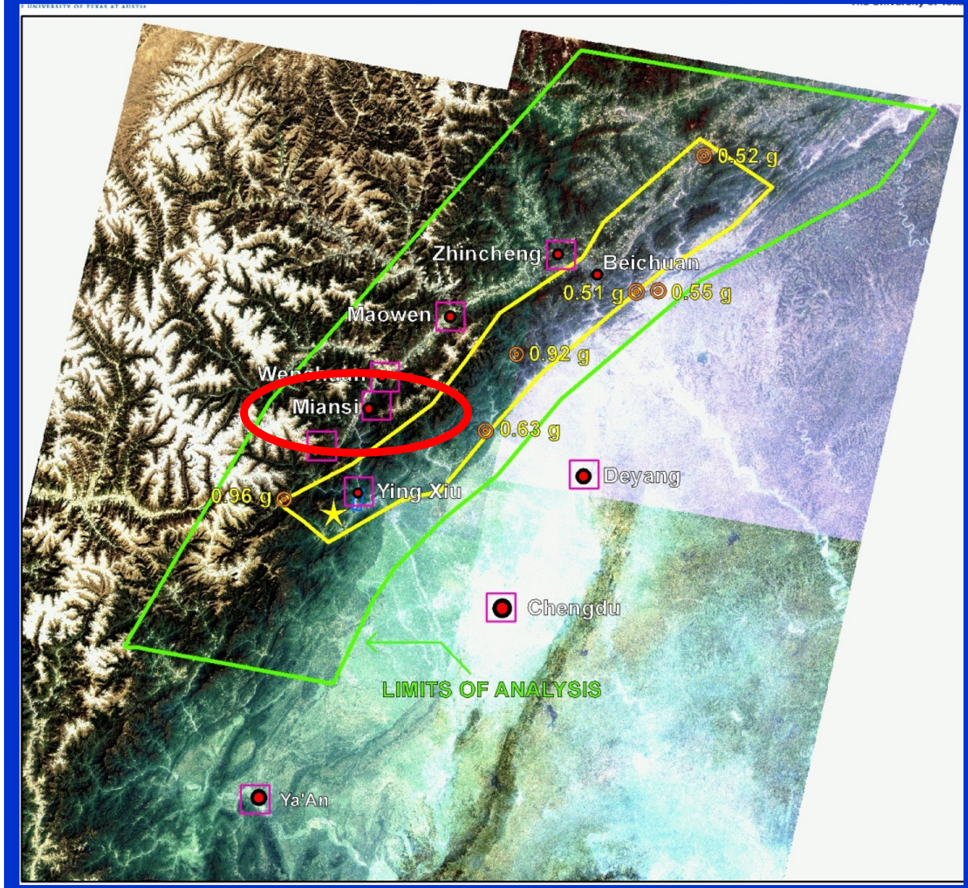
- Affected area larger than 10,000 km^2
- Significant landslides in mountainous area

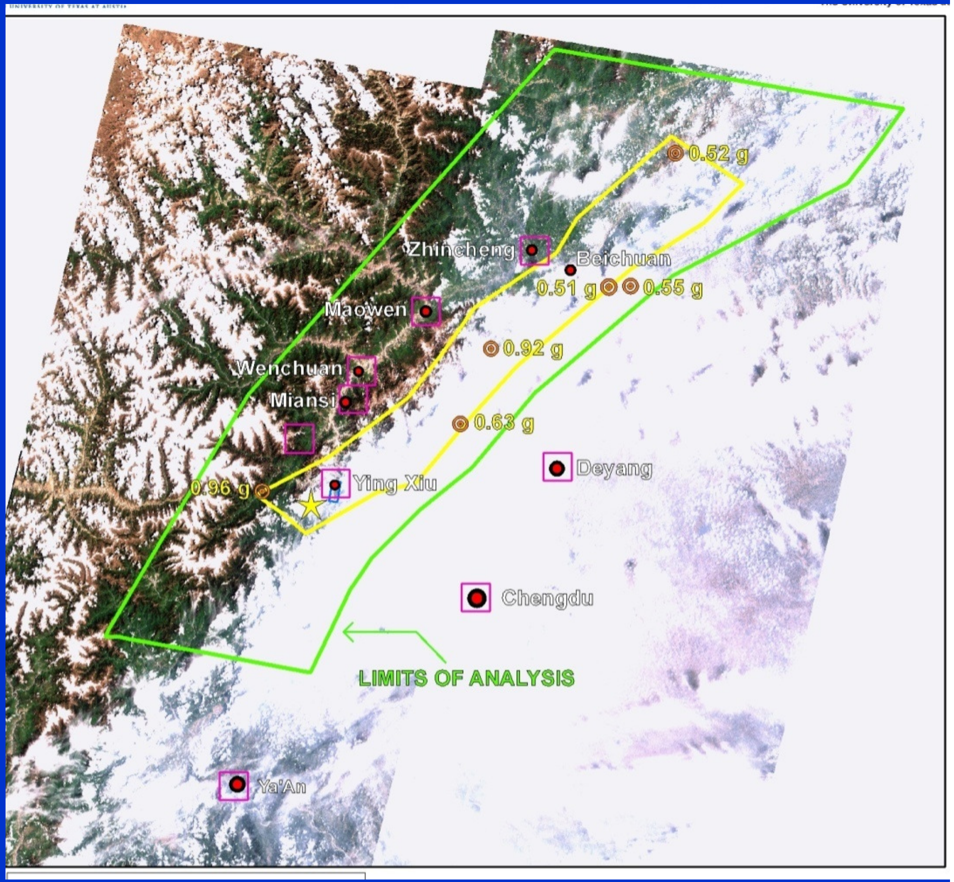
Wenchuan Earthquake

- LANDSAT Imagery
  - Cloud-free pre-event imagery (April 2007/2008)
  - Post-event imagery (May 2008) with significant cloud cover at edge of mountains
- High-resolution data
  - Post-event IKONOS (IK) imagery purchased by USGS and made available to researchers
  - Pre- and post-event Quickbird (QB) imagery purchased by Remote Sensing Consortium over localized areas

LANDSAT Imagery

Pre-event Imagery | *Post-event Imagery*





100 km

Landslide Identification

Pre-event LANDSAT

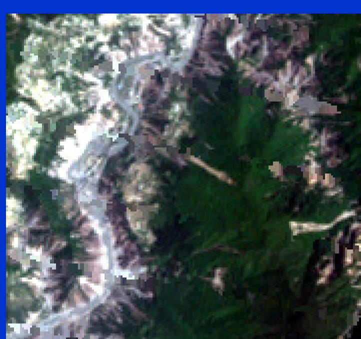
Post-event LANDSAT

~ 5 km x 5 km area

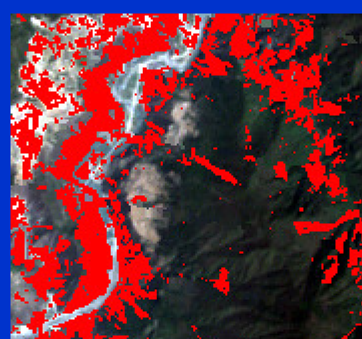
Post-event IKONOS

Wenchuan Earthquake

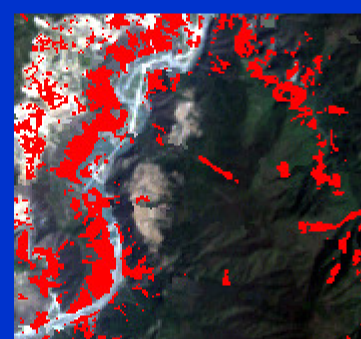
- Change Detection (LANDSAT)
  - Mid-infrared band (Mid IR, 1.55-1.75 μm) best distinguished landslides and minimized clouds
  - Clouds manually masked out
  - DNs converted to reflectance
  - Pre- and post-event imagery histogram matched
  - Difference > +0.10 → landslides



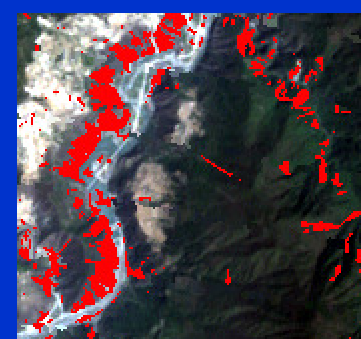
> +0.06



> +0.10

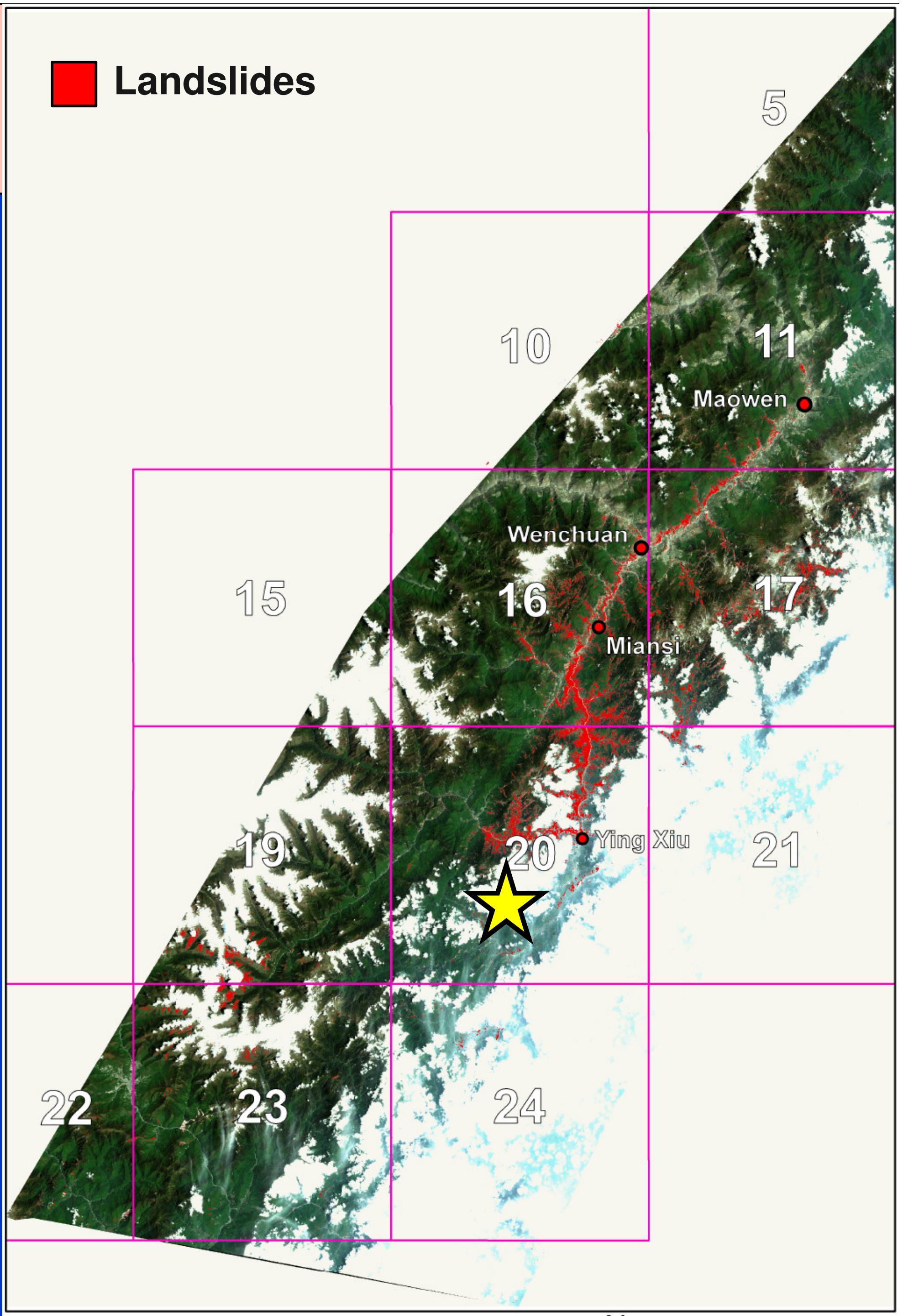


> +0.14



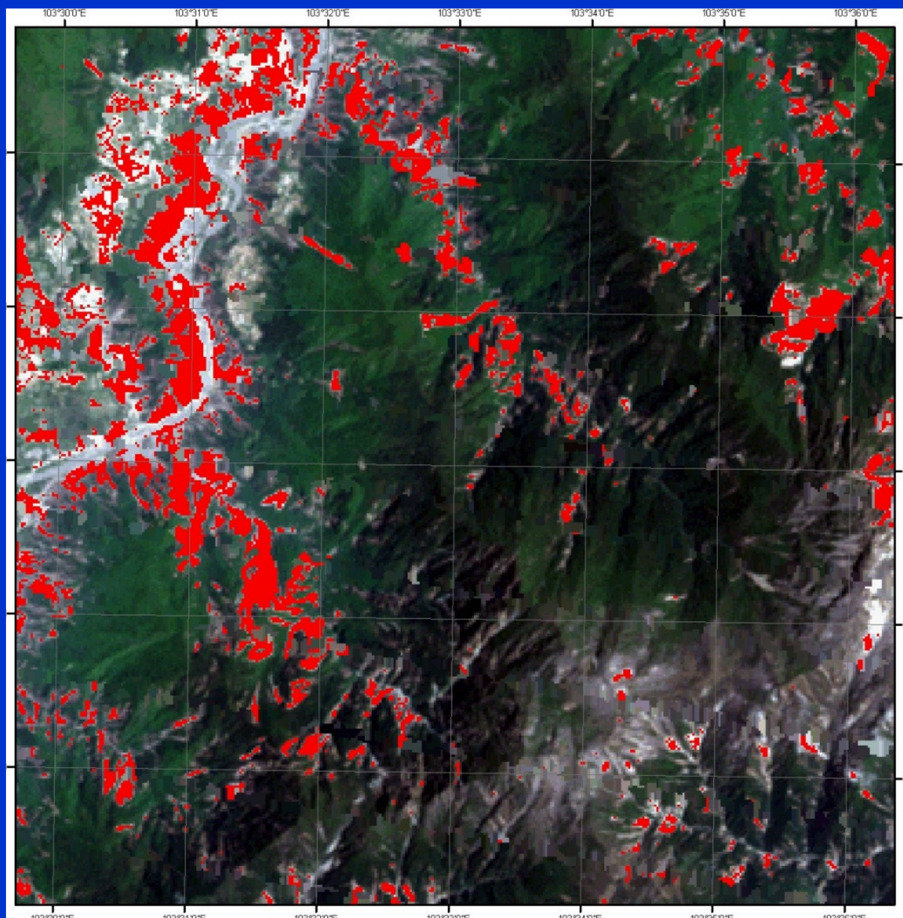
Results

- Heavy concentration of landslides near Ying Xiu and Miansi
- Fewer landslides to the west of epicenter

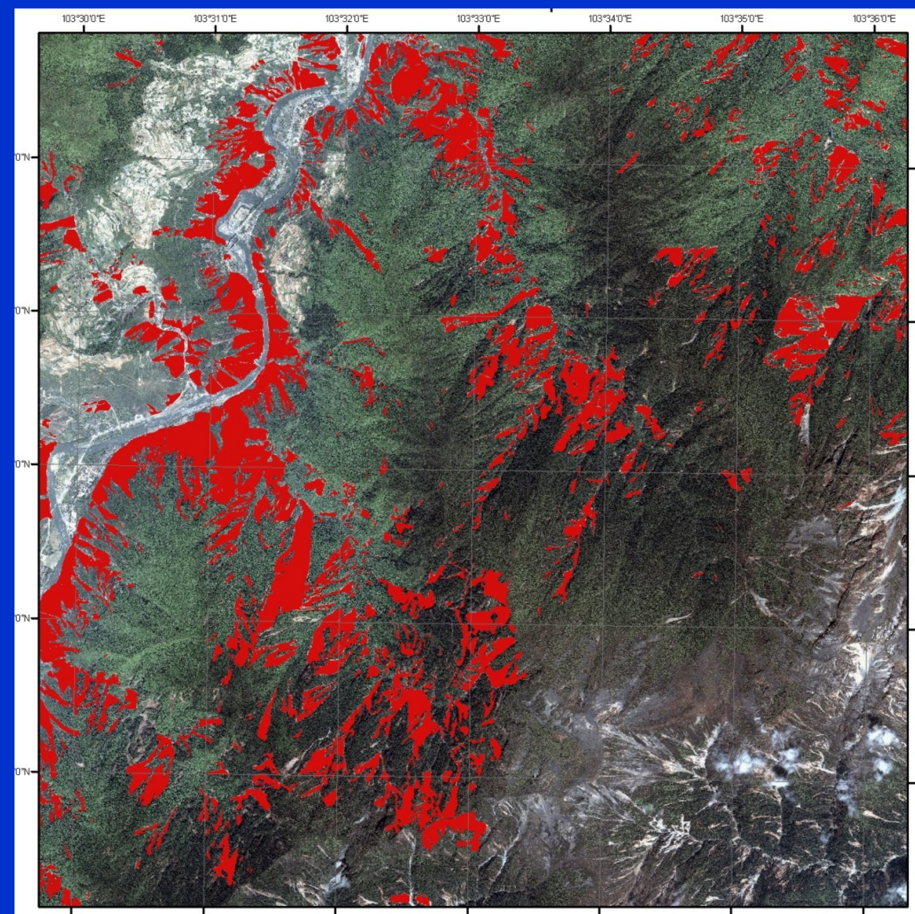


Miansi (PGA~0.92 g)

LANDSAT Analysis



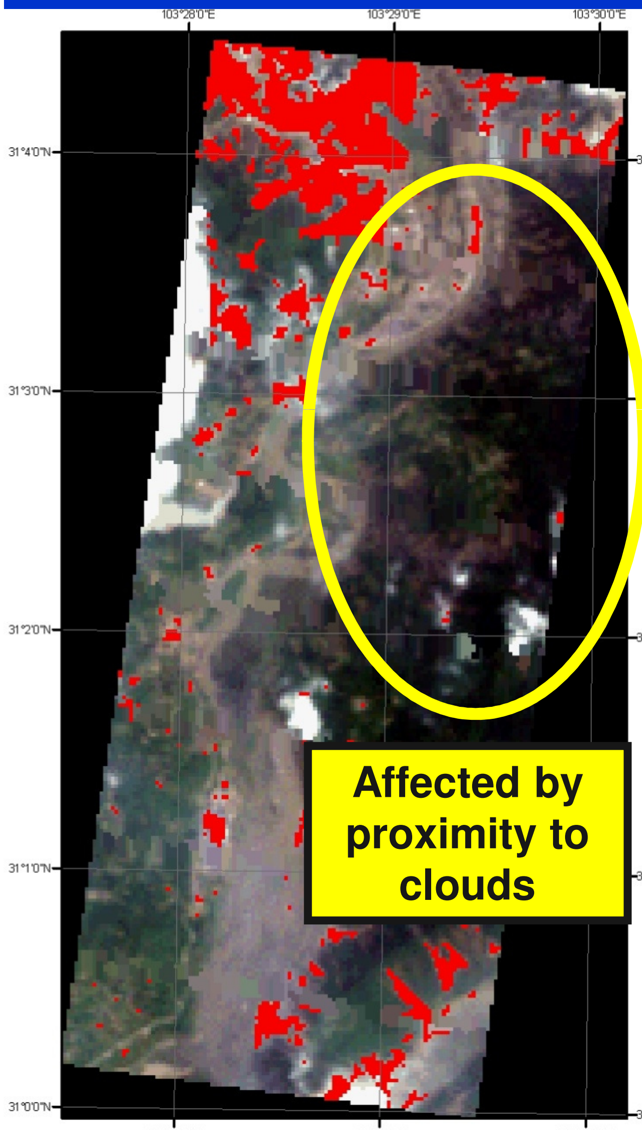
IK Visual Interpretation



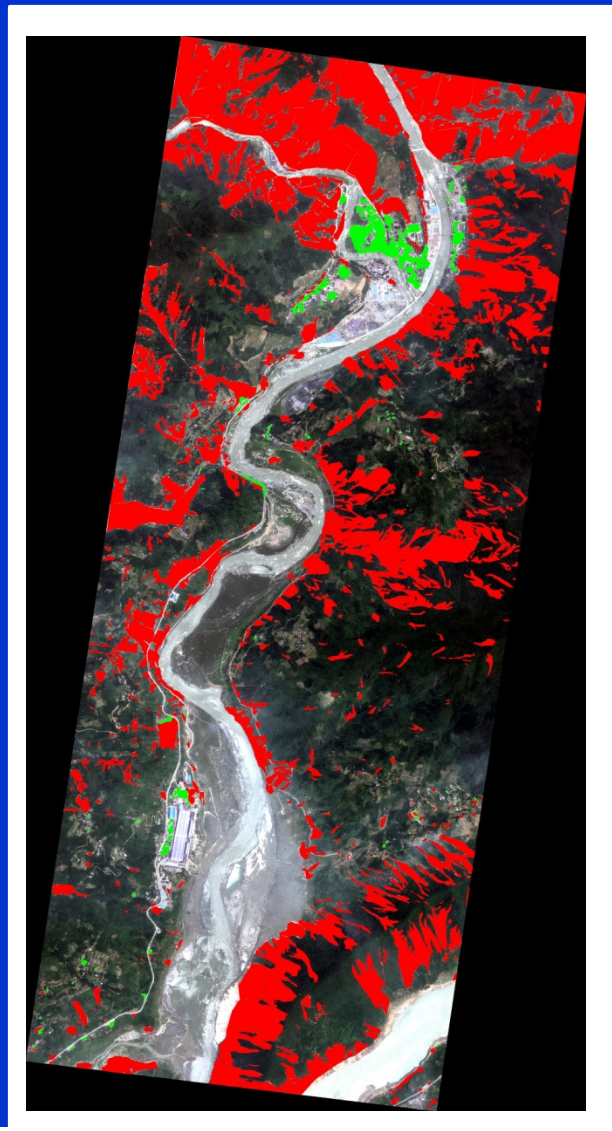
4 km

Ying Xiu (PGA~0.96 g)

LANDSAT Analysis



QB Visual Interpretation



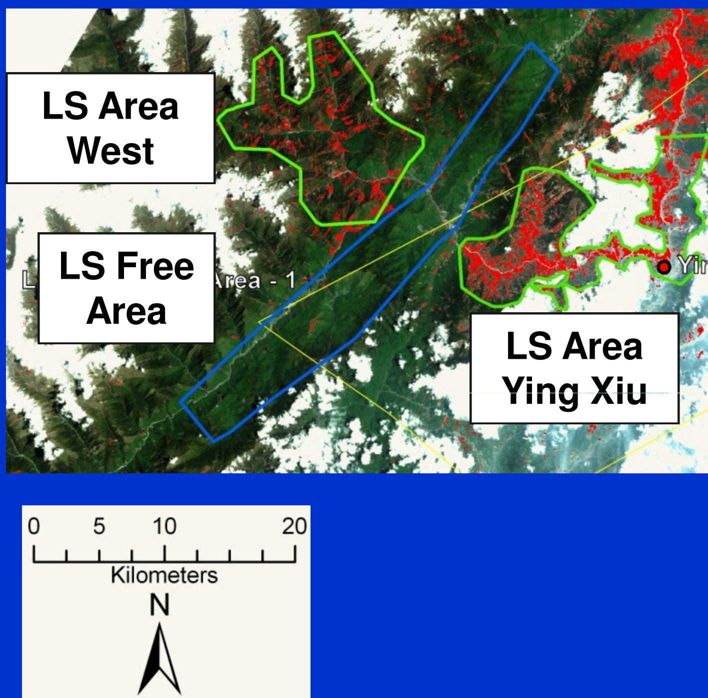
Landslides

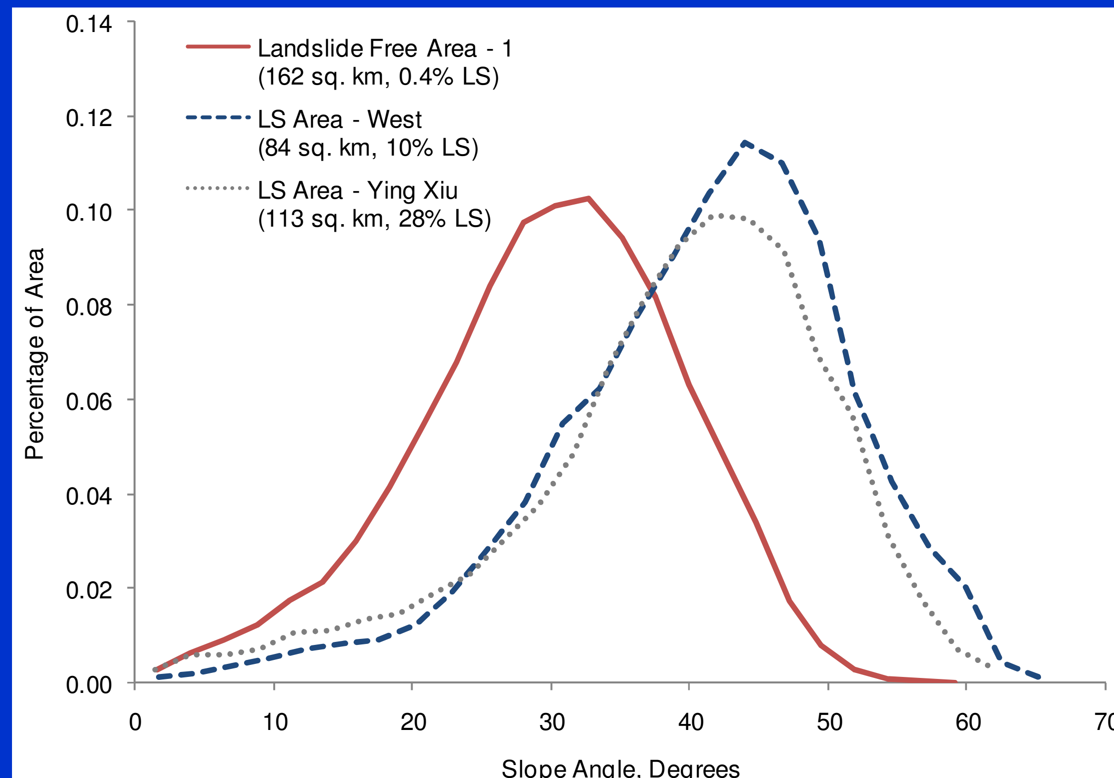
Urban damage

2 km

Data Fusion (Slope angles)

Slope angles derived from 90 m, gap-filled SRTM global DEM





Geology

LS Area Ying Xiu: Granite

LS Area West: Metamorphic schist, griotte

LS Free Area: Fractured sedimentary rocks

Remaining Challenges

- Training reconnaissance personnel
  - GPS, digital cameras
  - Geo-referencing (Google Earth)
  - Satellite imagery
- Development of coordinated field and remote sensing teams
  - True integration of data from these teams
- Acquisition time/interpretation time for remote sensing data