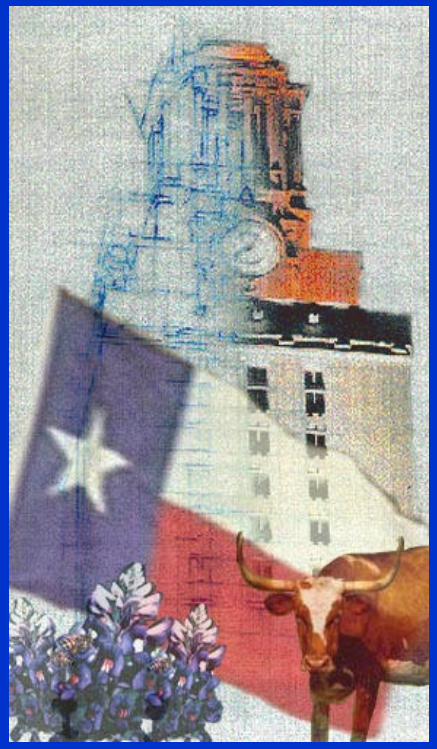
Using Satellite Images in Post-Earthquake Geotechnical Reconnaissance



Ellen M. Rathje
Melba M. Crawford
Sean Buckley
University of Texas at Austin
J.P Bardet
University of Southern California

GeoRecon Working Group Meeting
7 January 2004

Post-Earthquake Response

- Earthquake response hampered by inadequate information
  - Which areas are most damaged?
- Earthquake reconnaissance time wasted "looking" for damage, maps, etc.
- Optical satellite images can provide critical information to plan reconnaissance
- USGS-funded project to develop semi-automated methods to identify damage

High-Resolution Optical Satellites

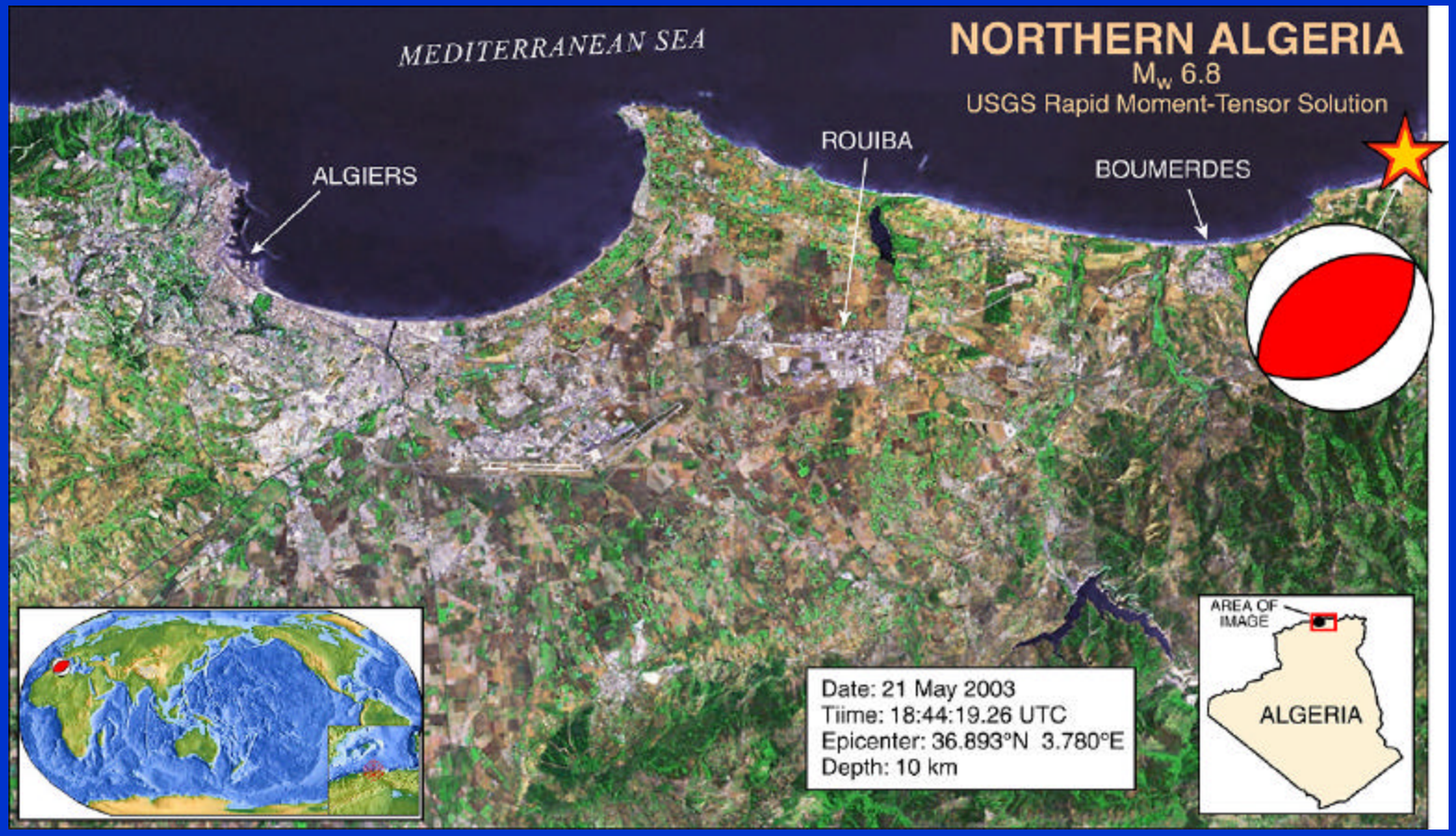
- Two commercial satellites
  - Quickbird (www.digitalglobe.com)
  - IKONOS (www.spaceimaging.com)
- Quickbird
  - 60 cm resolution panchromatic (B&W)
  - 2.4 m resolution multispectral (color)
- IKONOS
  - 100 cm resolution panchromatic (B&W)
  - 4 m resolution multispectral (color)

Optical Satellite Digital Data

- Panchromatic (black and white)
  - 450-900 nm band
- Multispectral (4 bands)
  - Blue 450-520 nm, Green 520-600 nm, Red 630-690 nm, Near Infrared 760-900 nm
- Pan-sharpened image
  - Fuse panchromatic and multispectral to obtain a high resolution color image

Northern Algeria Earthquake

- 21 May 2003, 7:44 pm, M_w 6.8



from neic.usgs.gov

Satellite Images

- 3 Quickbird images of Boumerdes
  - 22 April 2002, 11° OFF NADIR
  - 23 May 2003, 24° OFF NADIR
  - 18 June 2003, 8° OFF NADIR
- All images from DigitalGlobe archive
  - 25 km^2 minimum order size
  - ~$30/$km^2$ for standard pan/ms data
  - 2 to 3 day delivery
  - Tasking requires 64 km^2 minimum size

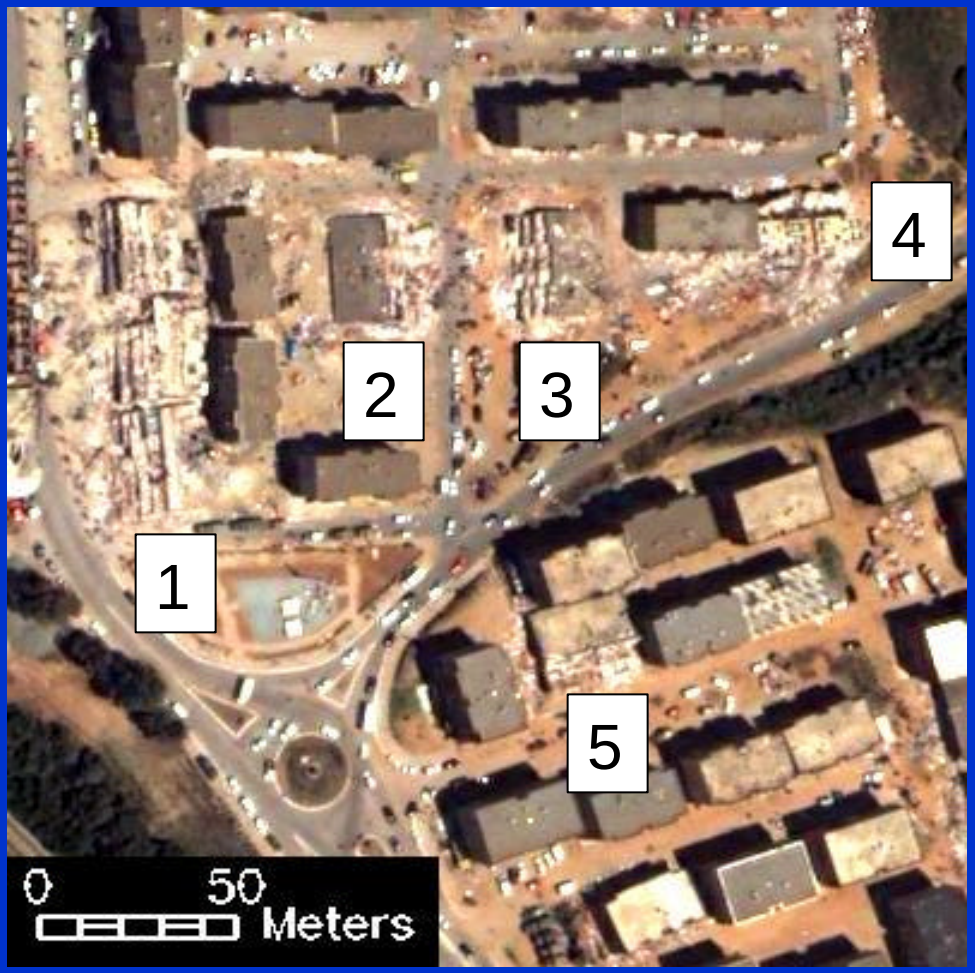
Boumerdes 23 May 2003

SW Boumerdes – April 02

Buildings, roads, and cars readily visible

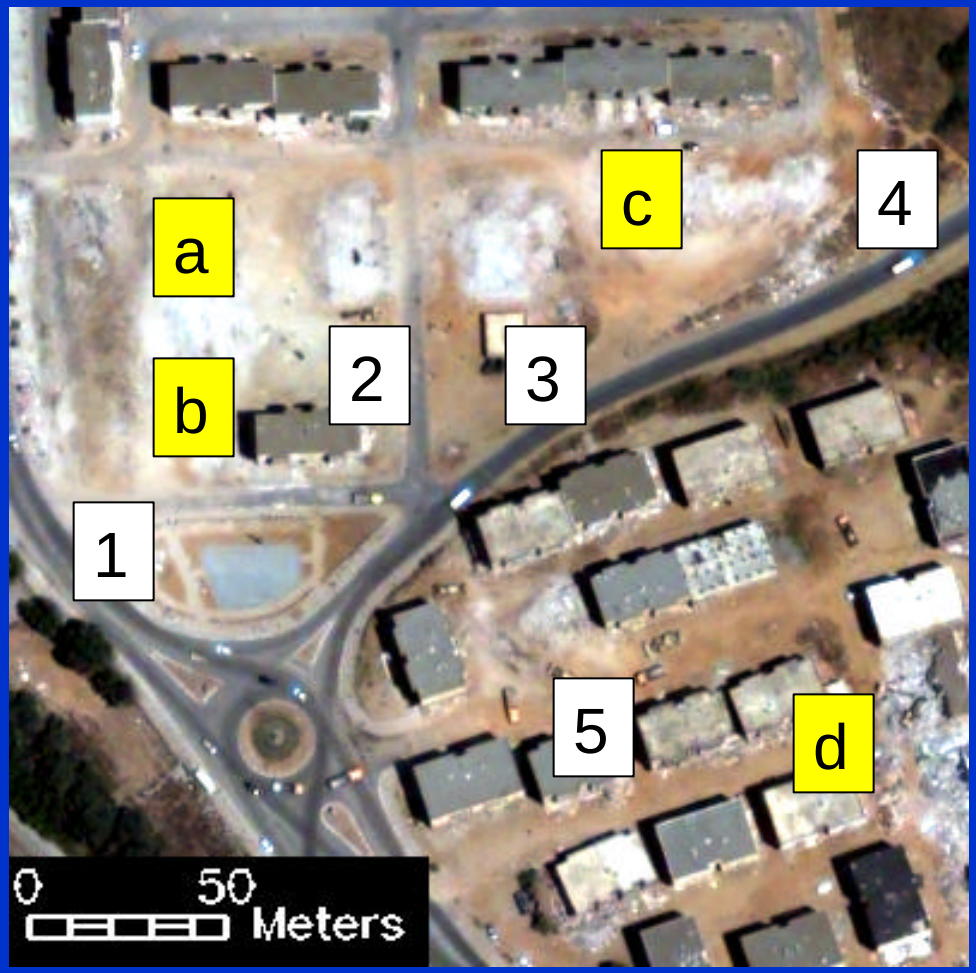
SW Boumerdes – May 03

- Pancaked buildings easily identified
- Note changes in color tones compared with previous image



SW Boumerdes – June 03

- Five pancaked buildings removed
- Other buildings removed



Damage Detection

- Visual inspection of images can provide valuable damage information
- Evaluating large areas require semi-automated methods
- Methods available
  - Change detection
  - Thematic classification

Change Detection

- Requires pre- and post-event images
- Images are co-registered
- Identify pixels that have changed
  - Image differencing, correlation
  - Principal component analysis
- Can identify strong, as well as moderate changes
- Affected by illumination, non-earthquake changes

Change Detection

Pre-event April 02

Post-event May 03

Non-Earthquake Changes

Pre-event April 02

Post-event May 03

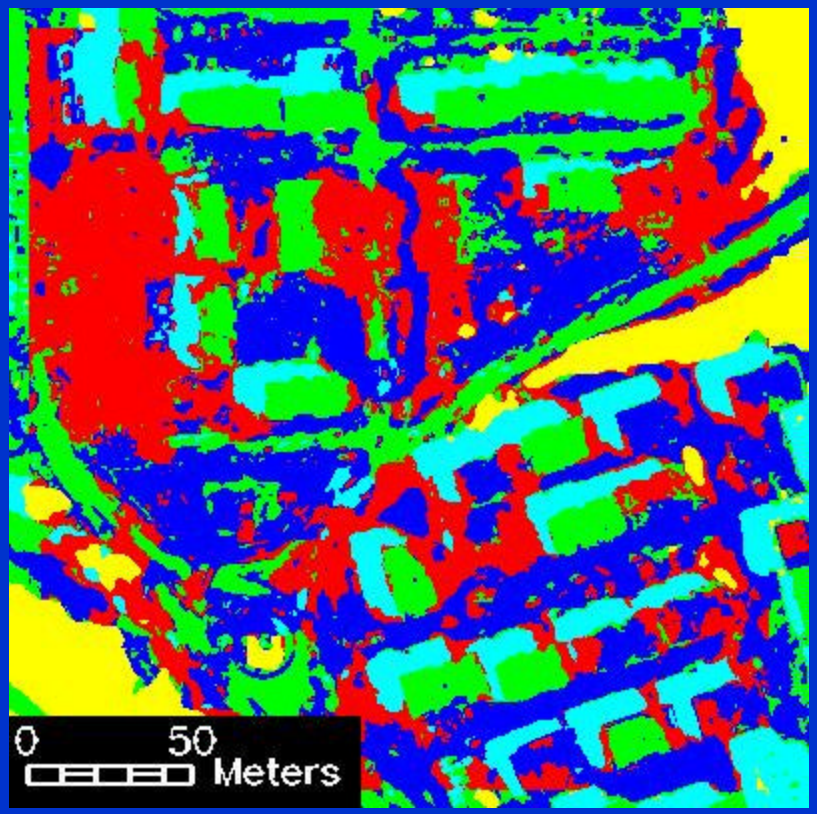
Thematic Classification

- Requires only post-event image
- Regions in image are classified based on distinguishing characteristics
- Potential characteristics
  - Spectral bands
  - Texture measures
- Requires significant distinguishable differences between damaged and non-damaged areas

Thematic Classification Results

Using spectral data (color) and texture measures

- Red – damage/debris
- Green – asphalt/non-damaged roofs
- Blue – soil
- Yellow – vegetation
- Cyan – shadow



Thematic Classification Results

For damage class (red)
9% omission error, 49% commission error

Current Status

- EERI purchased Algeria images for evaluation of use in reconnaissance
- EERI-sponsored workshop in September 2003 to discuss use of satellite images in earthquake reconnaissance
- EERI reconnaissance team going to Bam, Iran will have satellite image data (processed by ImageCat)

Satellite Images for Evaluation of Ground Deformation

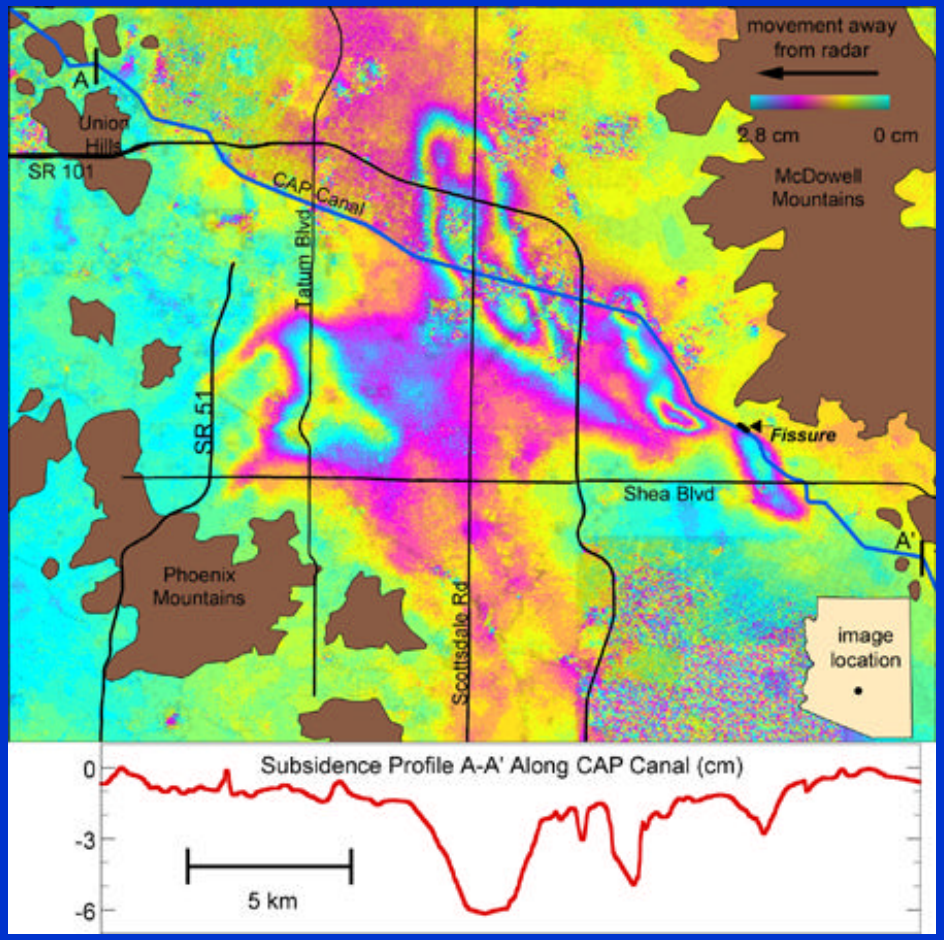
- NSF-Small Grant for Exploratory Research (Bardet, Rathje)
- Satellite images of Hokkaido Island from Sept 2003 Tokachi-oki earthquake
- 10-m resolution synthetic aperture radar (SAR) images of affected areas
- 2.5-m resolution panchromatic SPOT images (pre- and post-event)

SAR Interferometry (InSAR)

- Synthetic Aperture Radar (SAR)
  - Active microwave imaging
  - Phase preserving
  - Images acquired through clouds/night
- Interferometry (InSAR)
  - Uses two slightly offset images
  - Phase differences related to surface topography or line-of-sight deformations

Typical InSAR Results

Ground subsidence in Phoenix (Tatlow & Buckley 2003)

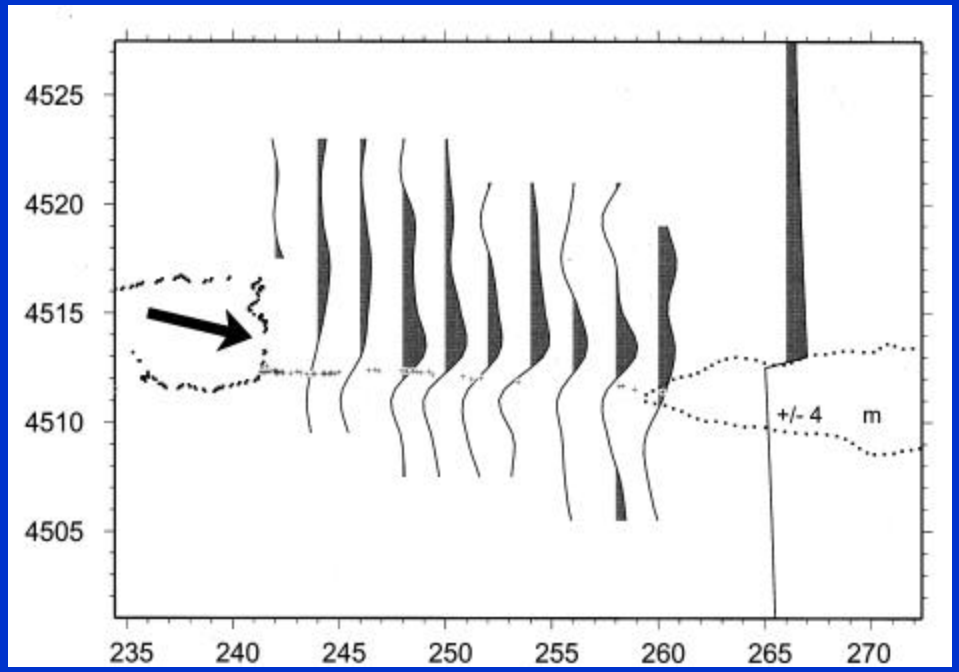


InSAR Issues

- Line-of-sight deformations
  - Good for vertical
  - Assumptions required for horizontal
- Sensitivity, saturation
- Loss of coherence
- Spatial resolution from satellites
  - Currently 10-m resolution, 1-3 m in next 2 yrs
- Airborne imaging
  - Better resolution, but must acquire before

Optical Images

- Cross-correlate pre- and post-event images to evaluate deformations
  - Horizontal only
  - Loss of coherence



Slip distribution from Kocaeli earthquake using 20-m resolution SPOT data (Fiegel et al. 2002, BSSA)