Using Satellite Images in Post-Earthquake Geotechnical Reconnaissance

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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 km² minimum order size
  - ~$30/km² for standard pan/ms data
  - 2 to 3 day delivery
  - Tasking requires 64 km² minimum size
Boumerdes 23 May 2003
Buildings, roads, and cars readily visible
SW Boumerdes – May 03

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