

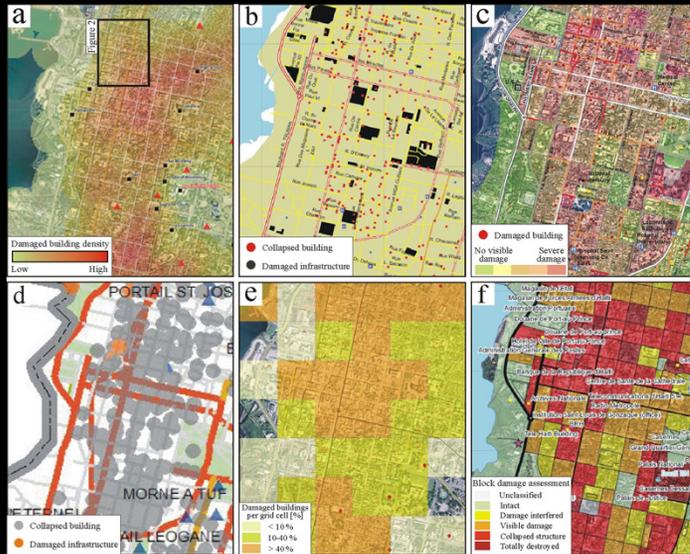
# Rapid and Reliable Damage Proxy Map From InSAR Coherence

Sang-Ho Yun<sup>1</sup>, Eric Fielding<sup>1</sup>, Mark Simons<sup>2</sup>, Piyush Agram<sup>2</sup>,  
Paul Rosen<sup>1</sup>, Susan Owen<sup>1</sup>, Frank Webb<sup>1</sup>

1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA
2. California Institute of Technology, Pasadena, CA, USA



# Damage Assessment Effort in Haiti



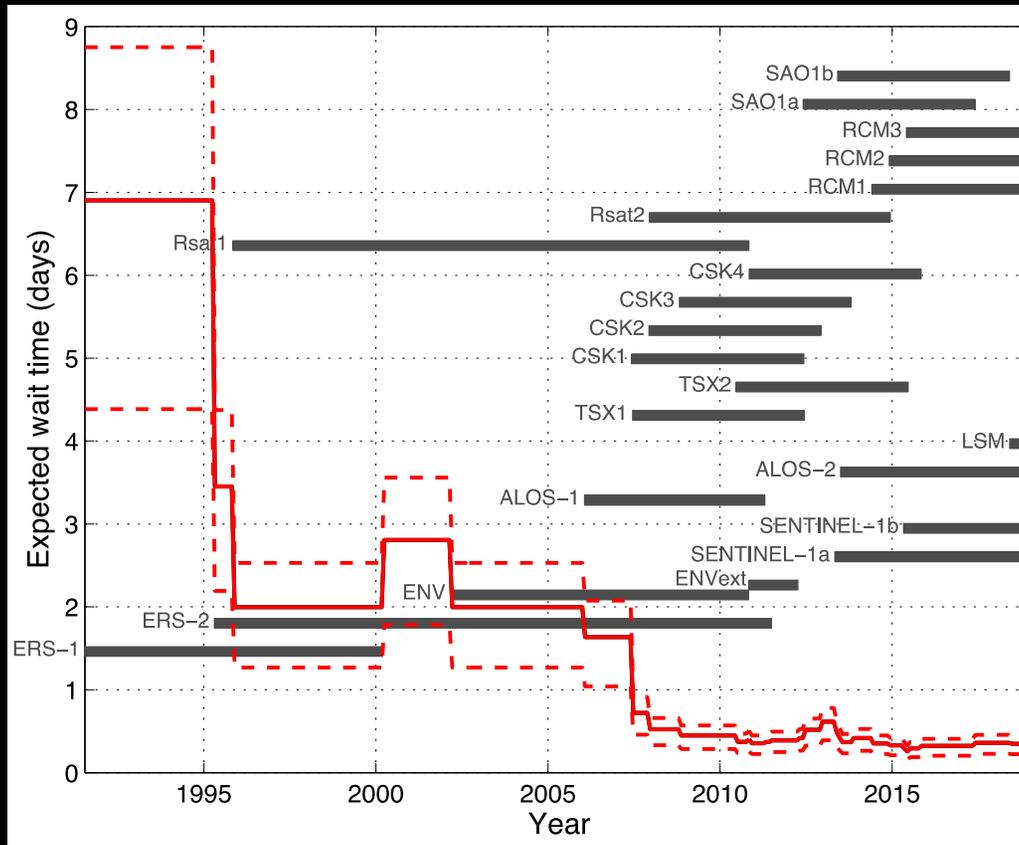
10,000 NGOs were estimated to be active.

More than 2000 damage maps for Haiti catalogued by Reliefweb.

Collaborative damage mapping results based on 50 cm satellite imagery and 15 cm aerial imagery by more than 500 expert volunteers organized by ImageCat for parts of Port-au-Prince.

Despite the superb data quality, only about 63% of the buildings mapped as severely damaged were identified as such.

# Data Acquisition Latency (all InSAR missions)



Expected wait time until the first SAR satellite to visit after an event

Ascending + descending orbit

Right-looking mode

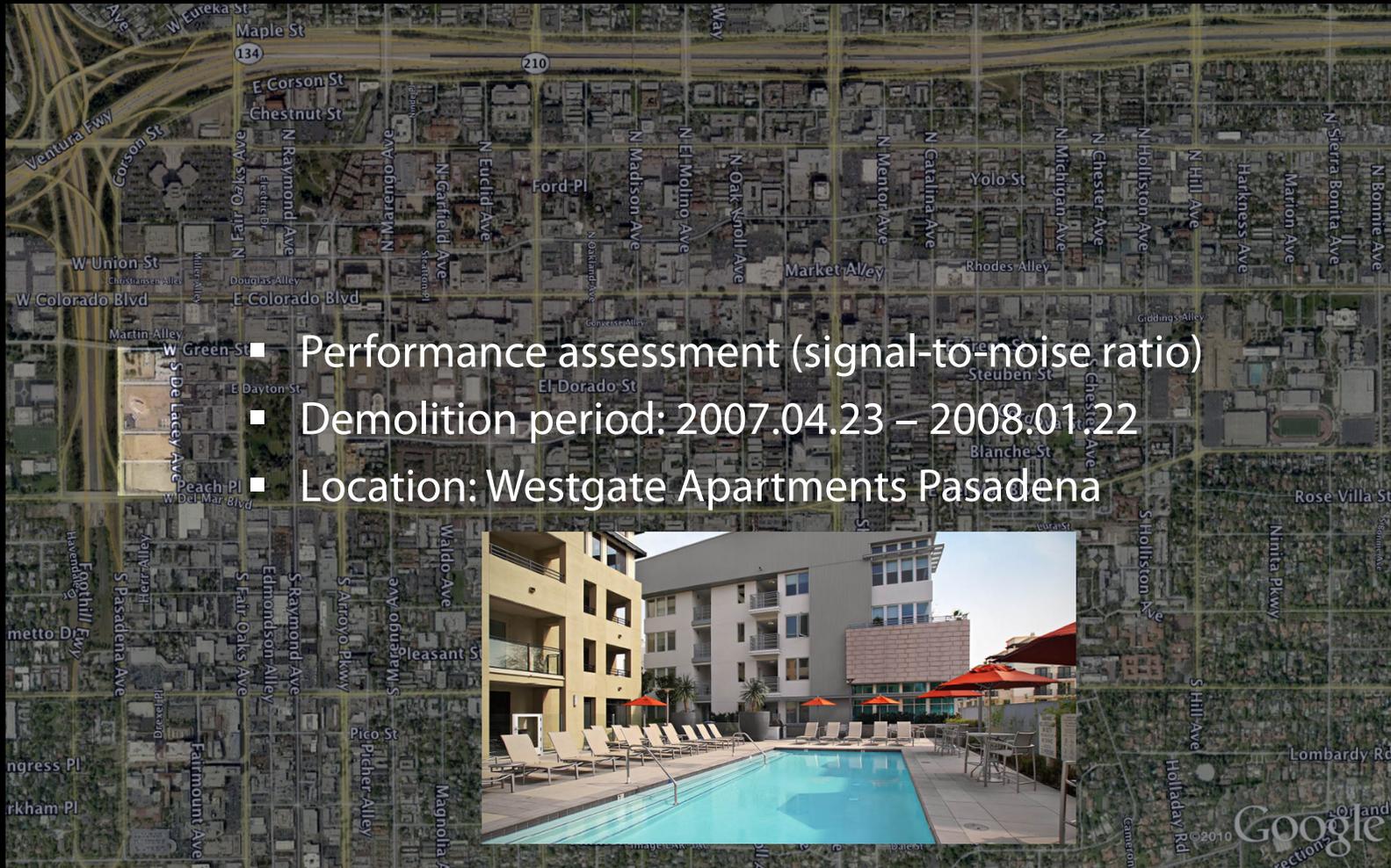
Latitude of 38° N/S

Present: 15 hours

2020: 8 hours



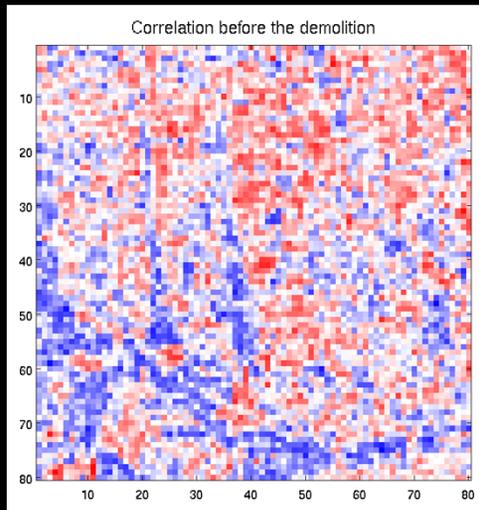
# Pasadena Building Demolition Project



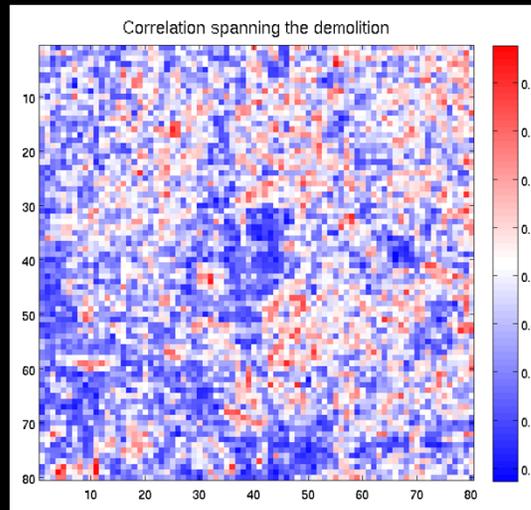
- Performance assessment (signal-to-noise ratio)
- Demolition period: 2007.04.23 – 2008.01.22
- Location: Westgate Apartments Pasadena



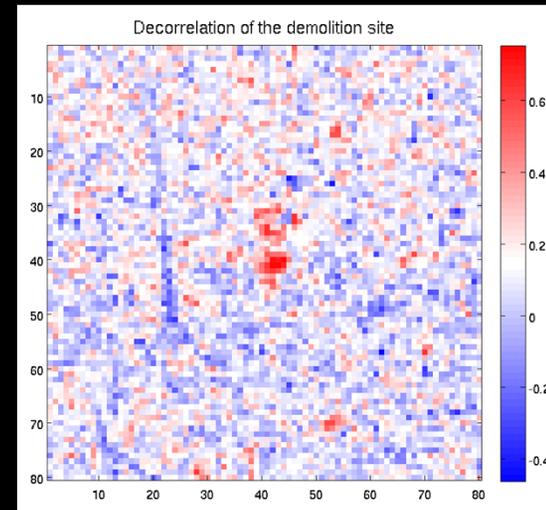
# Simple Difference



-

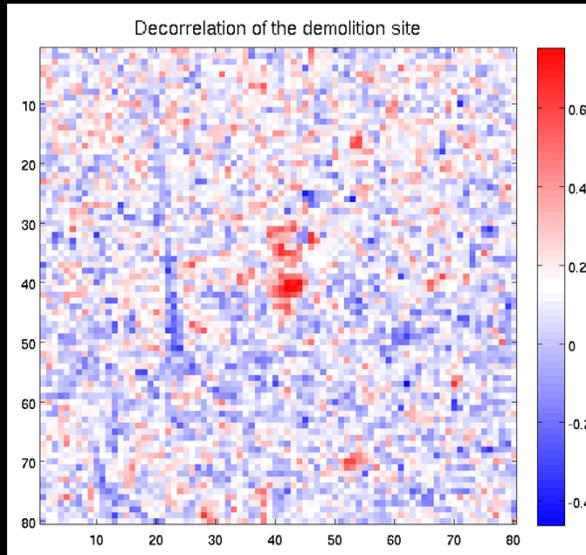


=

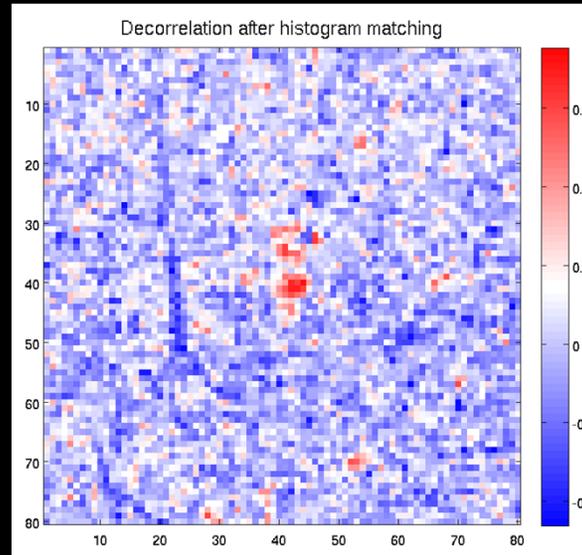


# Results

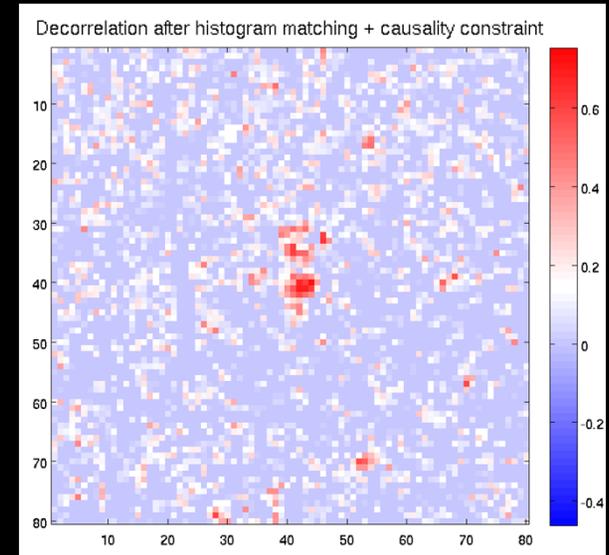
Simple Difference  
SNR = 17.3



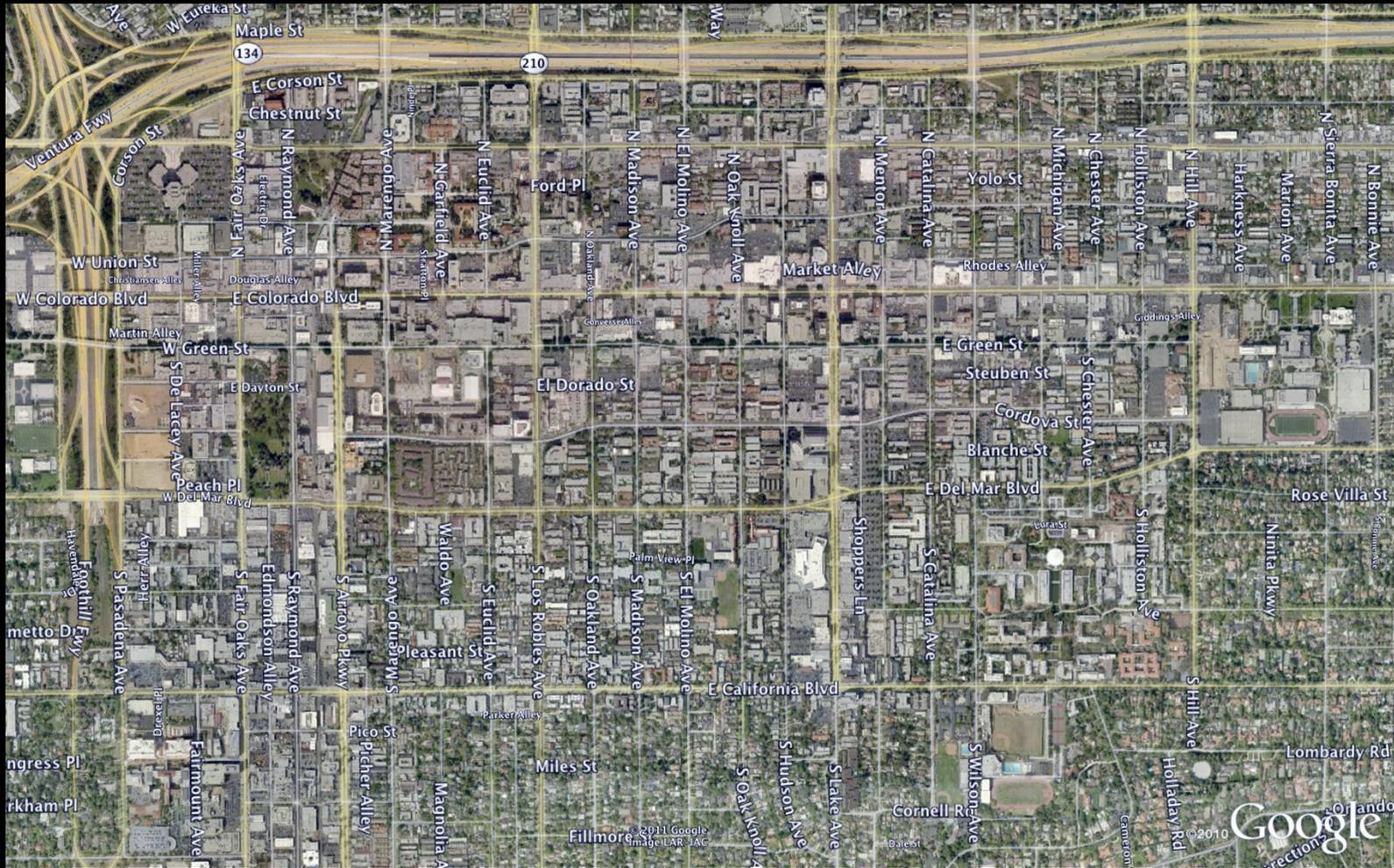
Histogram Matching  
SNR = 23.1



Causality Constraint  
SNR = 44.6

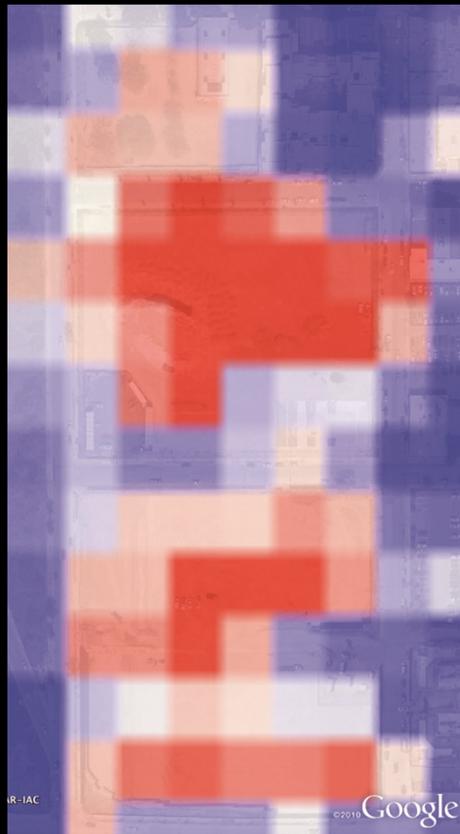


# Google Earth Image (2008.01.09)





# Site 1: Building blocks demolished



DPM



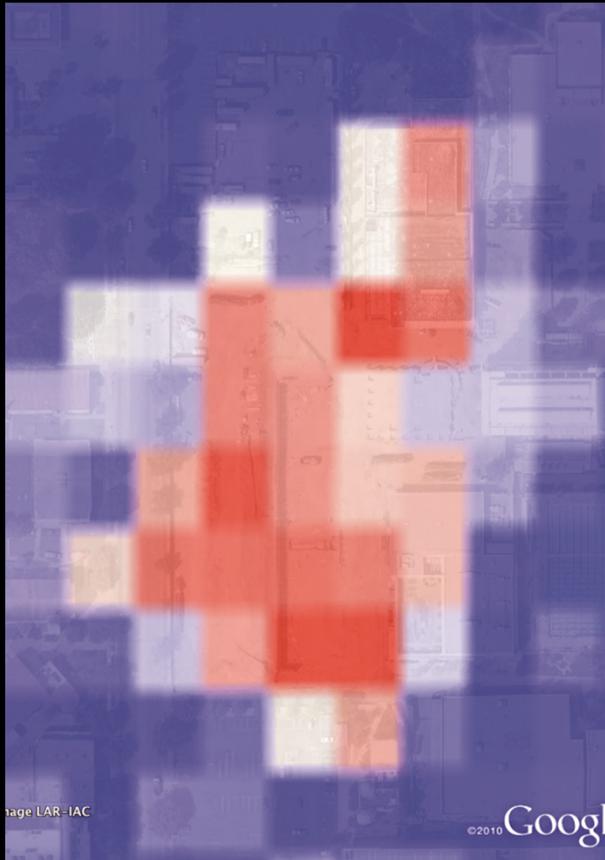
2007.10.23



2008.01.09



# Site 2: Pasadena City College remodeling



DPM

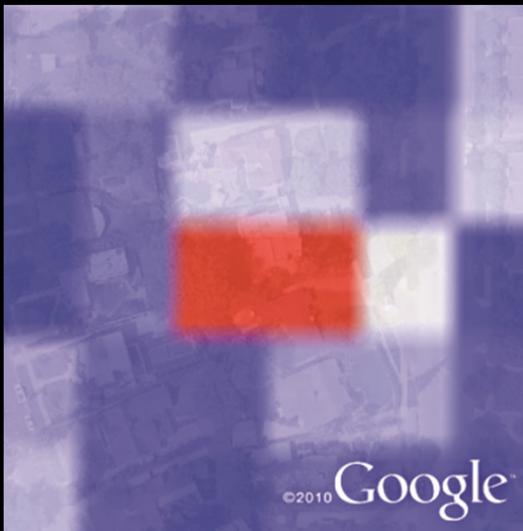


2007.10.23

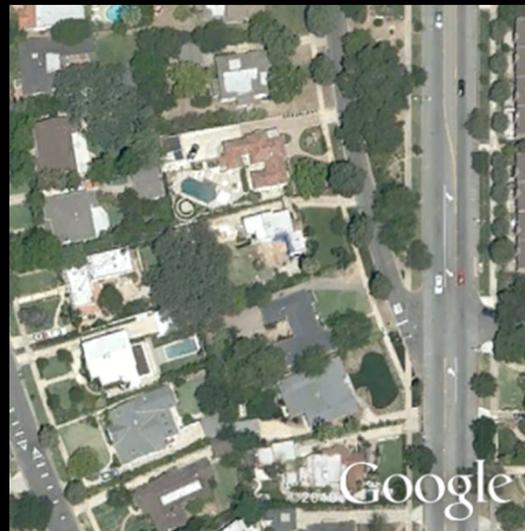


2008.01.09

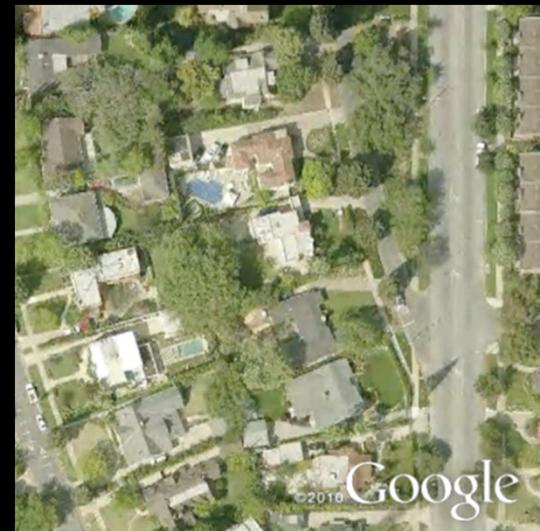
# Site 3: Single family house room addition



DPM



2007.10.23



2008.01.09

# Christchurch Earthquake

February 22, 2011

Magnitude 6.3

At least 181 people were killed

Peak acceleration: 1.88g

Extensive liquefaction producing  
400,000 tons of silt

Estimated cost: US \$12-13 billion

Damage assessment by NZ  
government under progress



# Ground Truth with Engineering Reports

**2010 CHCH EQ - LAND ENGINEERING REPORT**

EQC Claim Number: 2010/000771  
 Claimants Address: 1179 Clyde Rd, Ewaunton  
 Claimant Name: EA JOHNS  
 Engineer's Name: J. SCRIFIN  
 Engineers E-mail: scrifin@earthquake.co.nz  
 Date: 4/10/2011 Team no: 16

**LAND DAMAGE CATEGORY**  
 BLACK (L) RED (L) ORANGE (L) GREEN (L) BLUE (L)

**GENERAL**  
 Type of Damage: Earthquake Landslip Storm/Flood other  
 EQC Priority of claims: 1 - Home/Land seriously damaged and uninhabitable 2 - Home/Land seriously damaged but habitable 3 - Moderate damage to home/Land & Habitable 4 - Other damage  
 Is this natural Disaster Damage? YES NO  
 Is there an Imminent Risk of Loss? YES NO  
 Discussion with Claimant/Occupier: YES NO  
 What happened? Claimant's story: YES NO  
 Indications of a Disruption with Claimant(s): YES NO  
 SITE DESCRIPTION (Refer Site Plan and Cross Section): YES NO  
 General: NO LAND DAMAGE - SHAKING DAMAGE TO HOUSE  
 LAND - (DAMAGED ACCESS, LAND, & DESTROYED LAND, & RETAINING WALLS, BRIDGES, CULVERTS)  
 Type of damage to land: None  
 Retaining wall damaged? YES NO  
 Type of damage to retaining wall(s): YES NO  
 Location of retaining wall(s): YES NO  
 Land beneath Main access way damaged? YES NO  
 Access of land Damage: YES NO  
 Detailed Areas: YES NO  
 Estimated Land Remedial Cost: \$0 - \$250k \$250k - \$500k \$500k - \$1M \$1M - \$100k \$100k - \$250k

**DWELLING DESCRIPTION (Refer Site Plan and Cross Section)**  
 General: SINGLE STOREY BRICK WALL CLADDING, IRON ROOF, SLAB ON GRADE, GARAGE  
 BUILDING DAMAGE - GENERAL  
 Has the building been Damaged? YES NO  
 Is the Dwelling at Imminent Risk? YES NO  
 Estimated Remedial Value: \$0 \$10k - \$25k \$25k - \$50k \$50k - \$75k  
 Have any Apartment structures been damaged? YES NO  
 Are any apartment structures at Imminent Risk? YES NO  
 Have any services within 60 m of dwelling been damaged? YES NO  
 Are any services within 60 m of dwelling at Imminent Risk? YES NO  
 DAMAGED DWELLING APPURTENANT STRUCTURES, & SERVICES (Refer Site Plan and Cross Section)  
 Dwelling - features damaged: None external walls internal walls ceiling roof door/window frames chimney  
 Type of damage to Dwelling: cracks (walls) cracks (ceiling) cracks (window glass) cracks (chimney) floor sloping  
 Aspartentment structure(s) damaged: None gas/gasified carport dock tanks  
 What services have been damaged? water sewer drainage gas electrical telephone sewer structures other None  
 GENERAL: NO DAMAGE TO DRIVE OR OUTSIDE SURFACES - SHAKING DAMAGE ONLY  
 HOT WATER CYLINDER CRACKED 3 SAMPLES OF WATER IN CELLAR  
 BOEIL HUB MAIN CUT IN BRD

**EQC - Christchurch Land Engineering Report 2010** (Revision A: 5/10/2010) Claim No.: 2010/000771

**Floors and Foundations**  
 Timber floor on piles  
 Timber on internal piles with perimeter concrete footing  
 Concrete slab on grade

**Roof Cladding**  
 Light: Iron roof  
 Heavy: concrete tiles/clay tiles/slate etc

**Wall Cladding**  
 Light: weatherboard/plywood/stucco etc  
 Heavy: brick veneer/stone/solid plaster

**Type of Damage**  
 Stretching  
 Hoisting  
 Dishing  
 Racking/Twisting  
 Tilting  
 Discontinuous Foundation  
 Global Settlement

**Severity**  
 Minor  
 Mod

**Damage Scale**  
 0 to 5mm  
 0 to 20mm  
 0 to 20mm  
 0 to 10mm  
 0 to 20mm  
 0 to 10mm  
 0 to 50mm

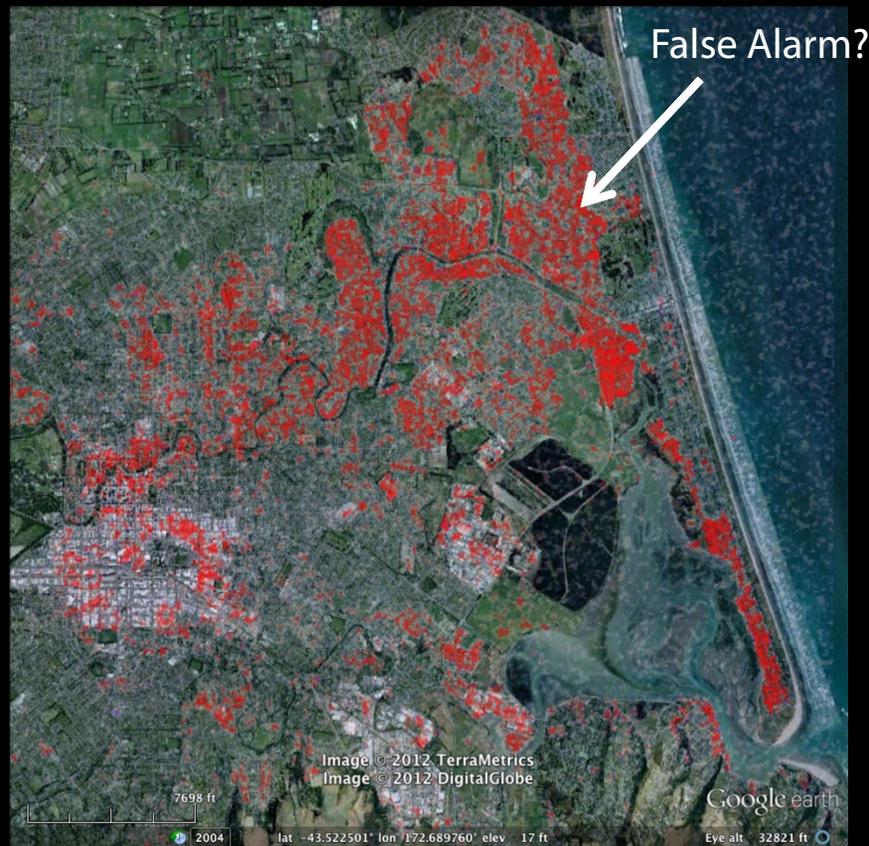
**Ground Truth**  
 1179 Clyde Road  
 Foundation  
 Access Shaken by 3 Flats  
 Clyde Road  
 No new EQC, ALL WITHIN 50m  
 Team 16  
 2010 case 771

Created by Tonkin & Taylor NZ  
 for CERA (Christchurch Earthquake Recovery Authority)



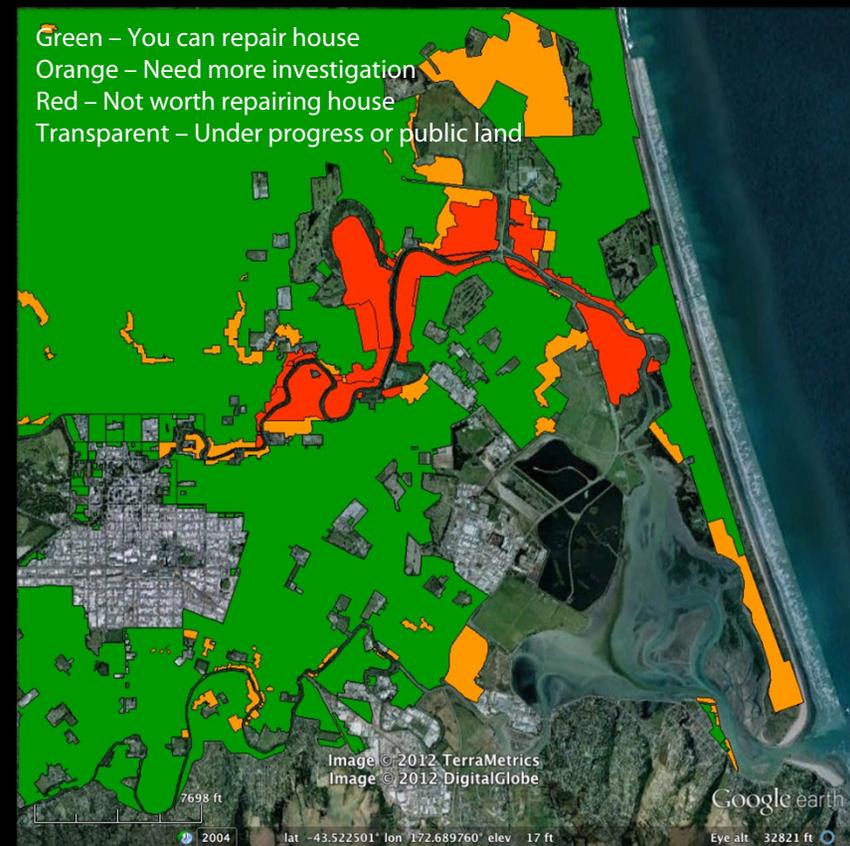
# Damage Proxy Map vs Ground Truth

From radar data acquired **3 days** after EQ



Damage Proxy Map (ALOS PALSAR A335):  
2010.10.10 – 2011.01.10 – 2011.02.25  
Google Earth (GeoEye) Image: 2011.02.26

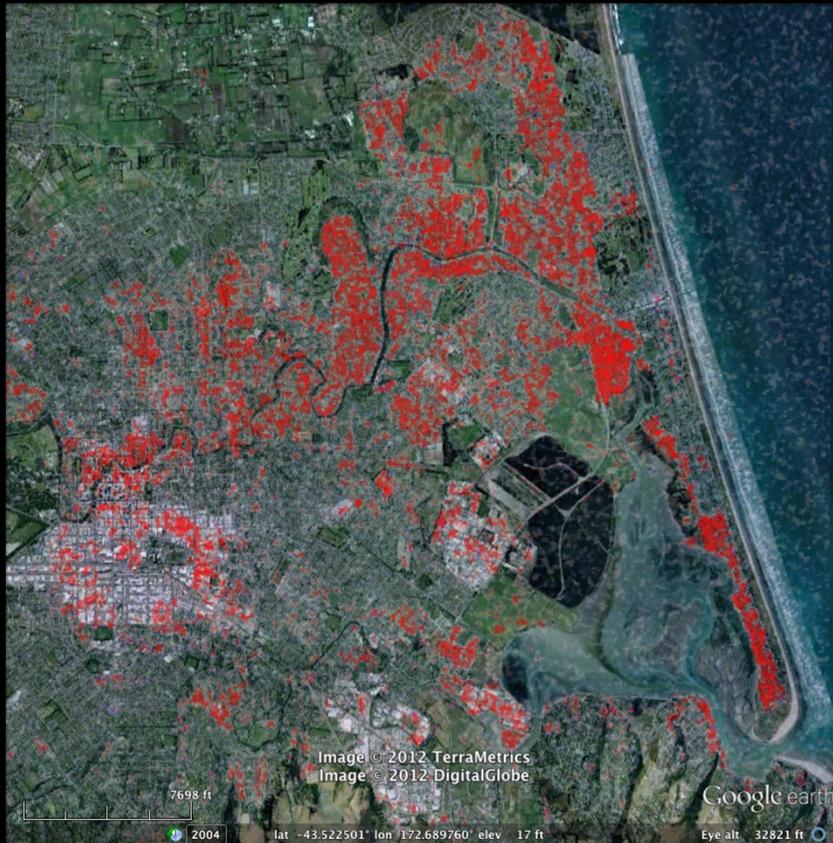
Zone Map first released **4 months** after EQ



2011.06.22 version  
Data provided by the New Zealand Government  
<http://data.govt.nz>

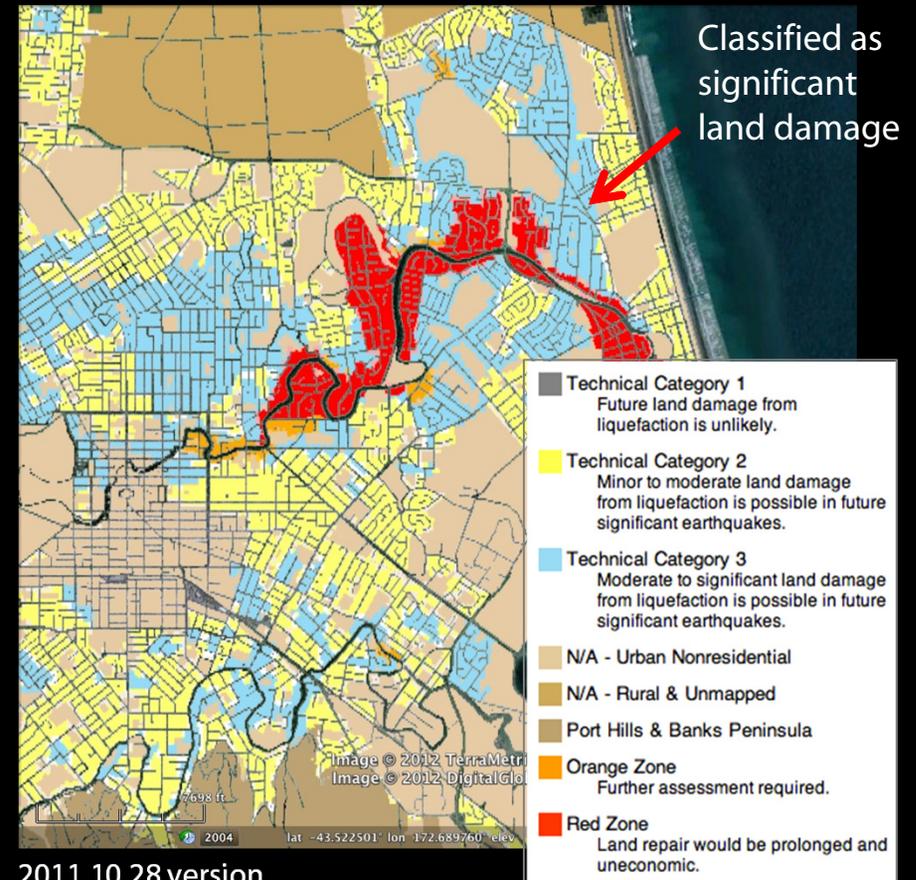
# Damage Proxy Map vs Ground Truth

From radar data acquired **3 days** after EQ



Damage Proxy Map (ALOS PALSAR A335):  
2010.10.10 – 2011.01.10 – 2011.02.25  
Google Earth (GeoEye) Image: 2011.02.26

Technical Classification Map first released **8 months** after EQ

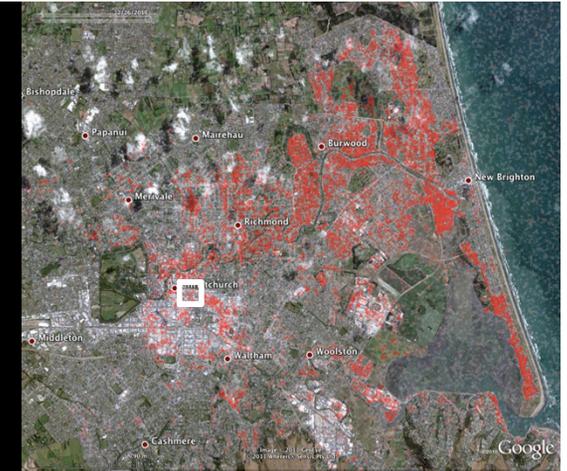


2011.10.28 version  
Data provided by the New Zealand Government  
<http://data.govt.nz>

# Christchurch Cathedral



Christchurch Cathedral on the day of the earthquake (REX/The Telegraph)



Damage Proxy Map



2010.09.03



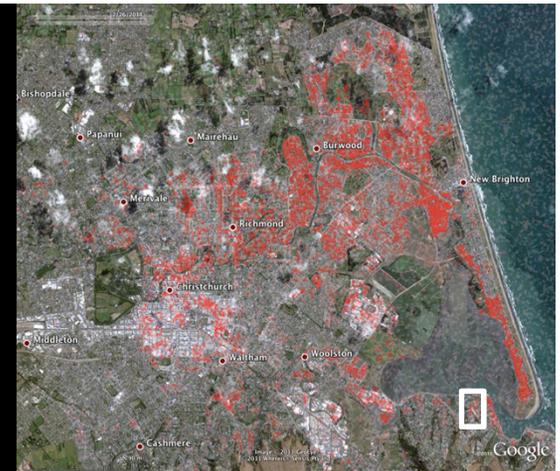
2011.02.23



# Cliff Collapse



Photo Courtesy David Petley



Luxury homes teeter on the edge after huge landslides in Redcliffs, near Christchurch (Photo by Torsten Blackwood from AFP).



Damage Proxy Map



2010.09.03



2011.02.23

**EQ M6.3**



2011.02.26



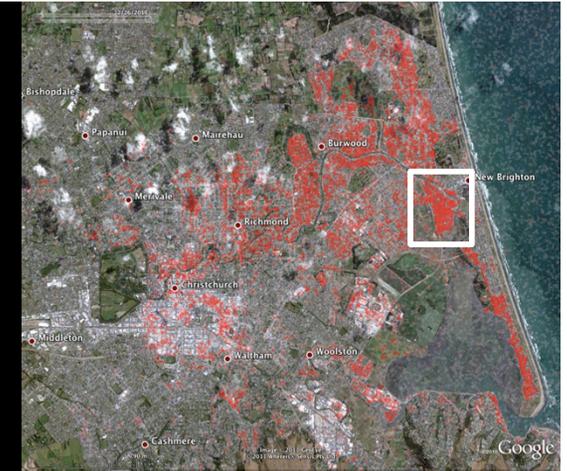
# Liquefaction in Bexley



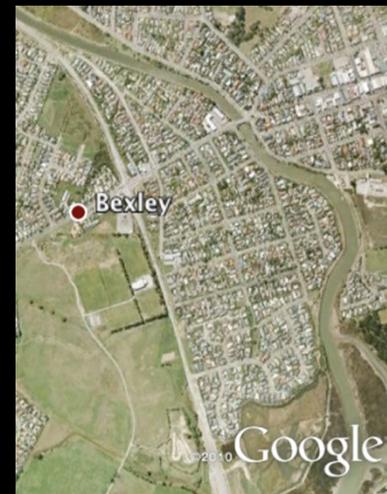
Cars stuck in the mud, Bexley  
(Brett Phibbs/AFP/Getty Images)



Water Inundated Bexley (Mark Mitchell/New Zealand Herald/Associated Press)



Damage Proxy Map



2009.03.04



2011.02.23



# Tohoku Earthquake

March 11, 2011

Magnitude 9.0

At least 15,822 people were killed

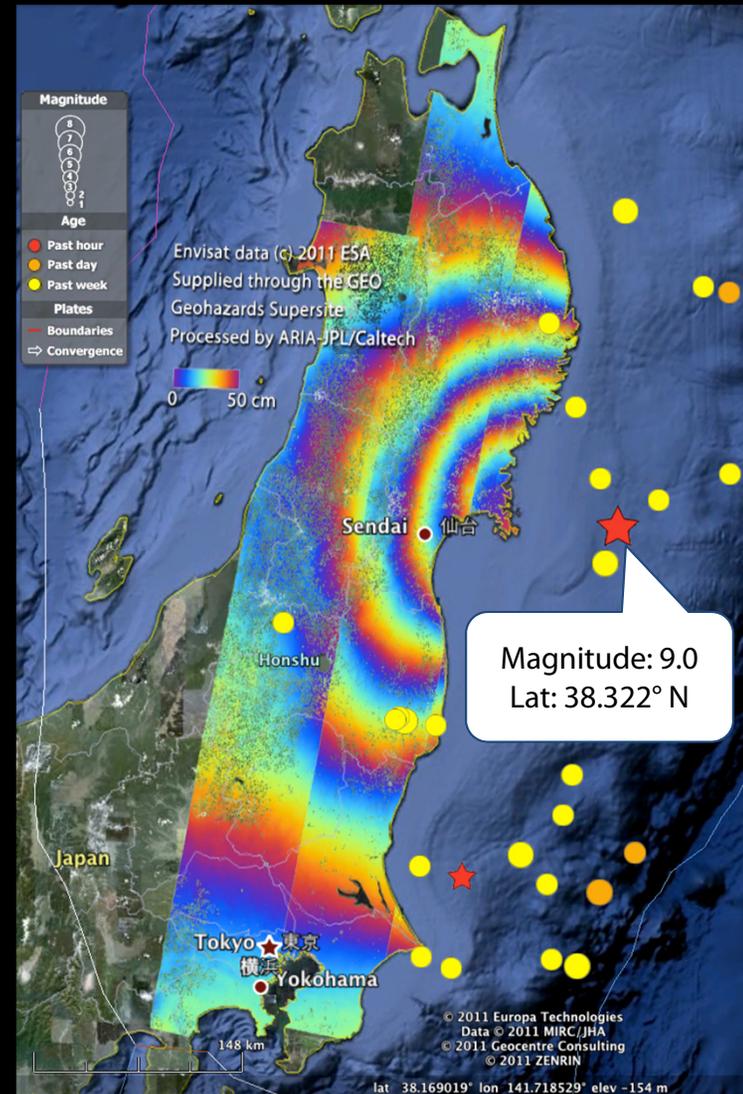
3,926 people missing

125,000 buildings damaged/destroyed

Estimated cost: US \$300 billion

Damage assessment by Japanese government under progress

Envisat (C-band) Interferogram:  
One color cycle = 50 cm LOS disp.



ARIA product, featured in NASA photo journal, ESA portal, and GEO supersite

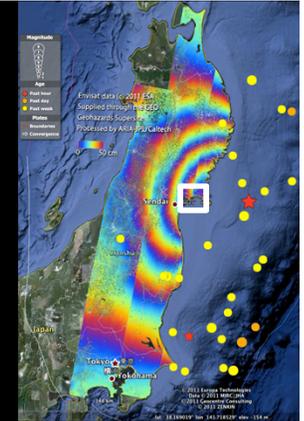


# Damage Proxy Map from Coherence Change and Amplitude Change

Ishinomaki, Japan

Envisat (ESA, C-band) ASAR

2011.01.31-2011.03.02-2011.04.01



Coherence change: Building damage due to tsunami waves



Amplitude change: Inundated areas as of 2011.04.01

# Conclusions and Future Work

Future radar satellites will visit SoCal within a day after a disaster event. Data acquisition latency in 2015-2020 is 8~15 hours. Data transfer latency that often involves human/agency intervention far exceeds the data acquisition latency. → Need interagency cooperation to establish automatic pipeline for data transfer.

The algorithm is tested with ALOS PALSAR data of Pasadena, California. Quantitative quality assessment is being pursued: Meeting with Pasadena City Hall computer engineers for a complete list of demolition/construction project → 1. Estimate the probability of detection and probability of false alarm 2. Estimate the optimal threshold value.

The algorithm will be improved under a NASA fund (Program: Applications of Geodetic Imaging, PI: Sang-Ho Yun), utilizing temporal characteristics of coherence and be optimized for each type of data (UAVSAR, TerraSAR-X, COSMO-SkyMed, Sentinel-1 a/b, US L-band SAR Mission<sup>\*</sup>)

<sup>\*</sup> Proposed Mission - Pre-decisional - for Planning and Discussion Purposes Only

