Lessons from Response to Superstorm Sandy using COSMO-SkyMed Radar Satellites to Produce Damage Proxy Maps of New York City

Sang-Ho Yun, Eric Fielding, Tom Farr, Frank Webb, Paul Rosen, Susan Owen – Jet Propulsion Laboratory, California Institute of Technology

Mark Simons – California Institute of Technology

Alessandro Coletta, Pietro Milillo, Giovanni Milillo – ASI (Italian Space Agency)

Shoreh Elhami – GISCorps

Don Ferguson – US Department of Energy

John Helly – University of California, San Diego

Advanced Rapid Imaging and Analysis (ARIA) Overview

JPL

Integrating
Space Geodesy
Seismology
Modeling

Seismological Laboratory
California Institute of Technology

"This is exactly the kind of product we are looking for", A. Rosinski,Cal GS

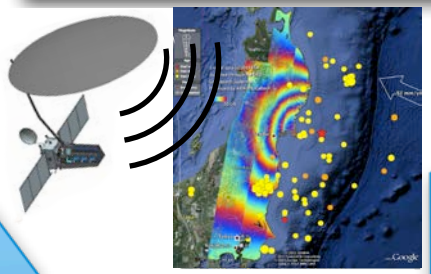
Radar Spacecraft

GPS Networks

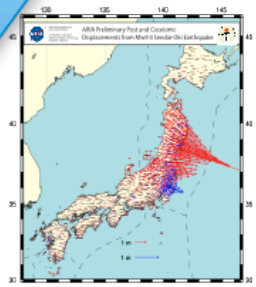
Seismic Networks

Optical Sensors

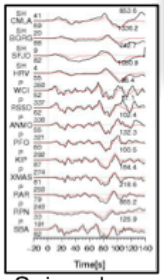
Automated Data Collection and Processing



Radar



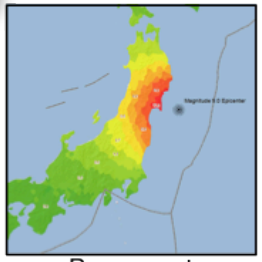
GPS



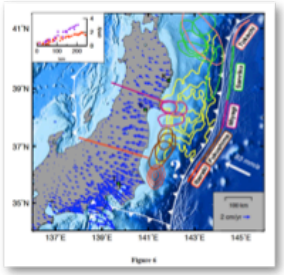
Seismology

Monitoring and Near Real-time Assessment

Damage Proxy Inundation



Permanent Ground Deformation



High Resolution Hazard Assessment from Fault Models

Examples from the 2011 M9.0 Tohoku-Oki (Japan) earthquake

Potential Partners

NASA

asi agenzia spaziale italiana

USGS science for a changing world

U.S. Department of Homeland Security

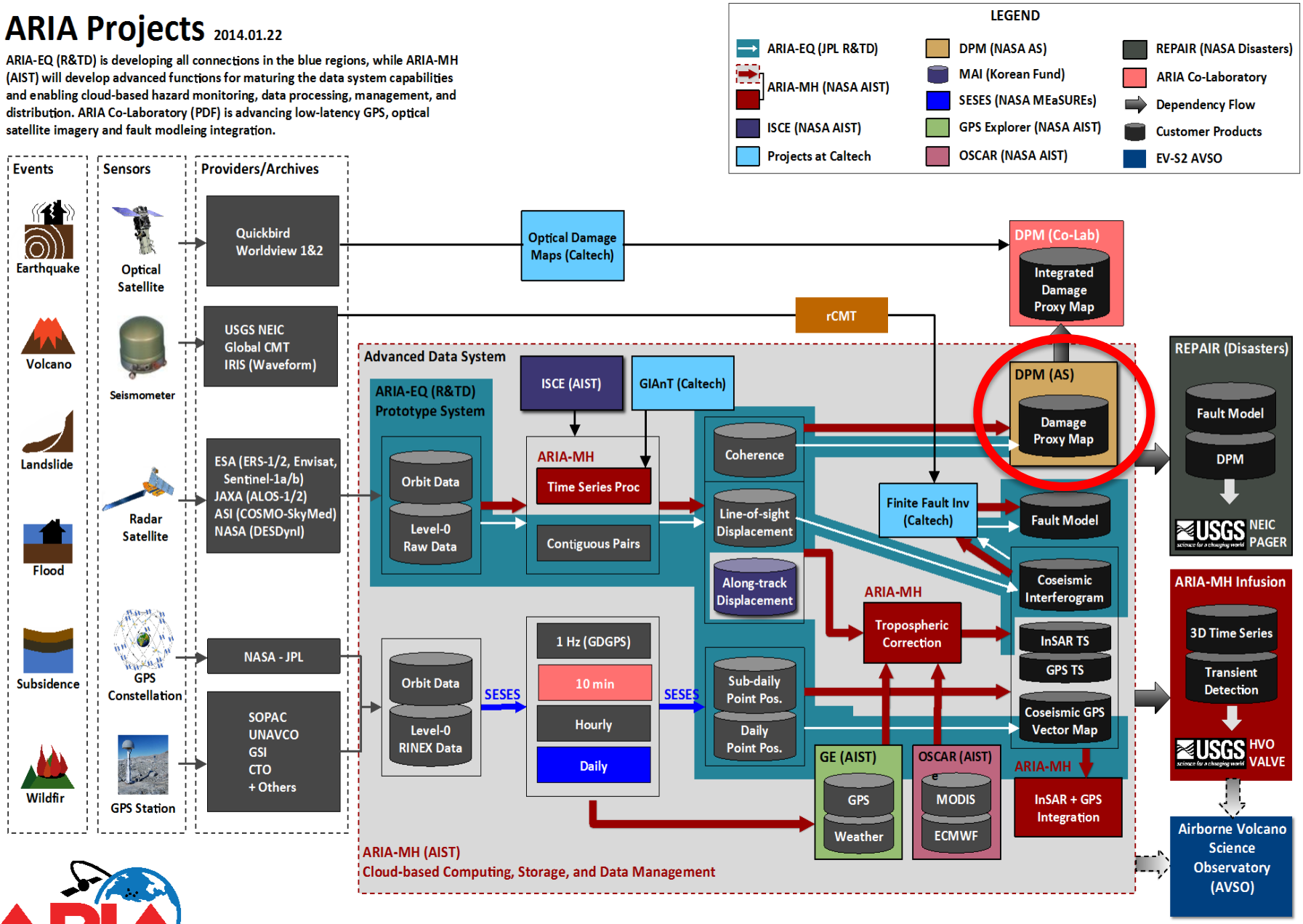
NSF

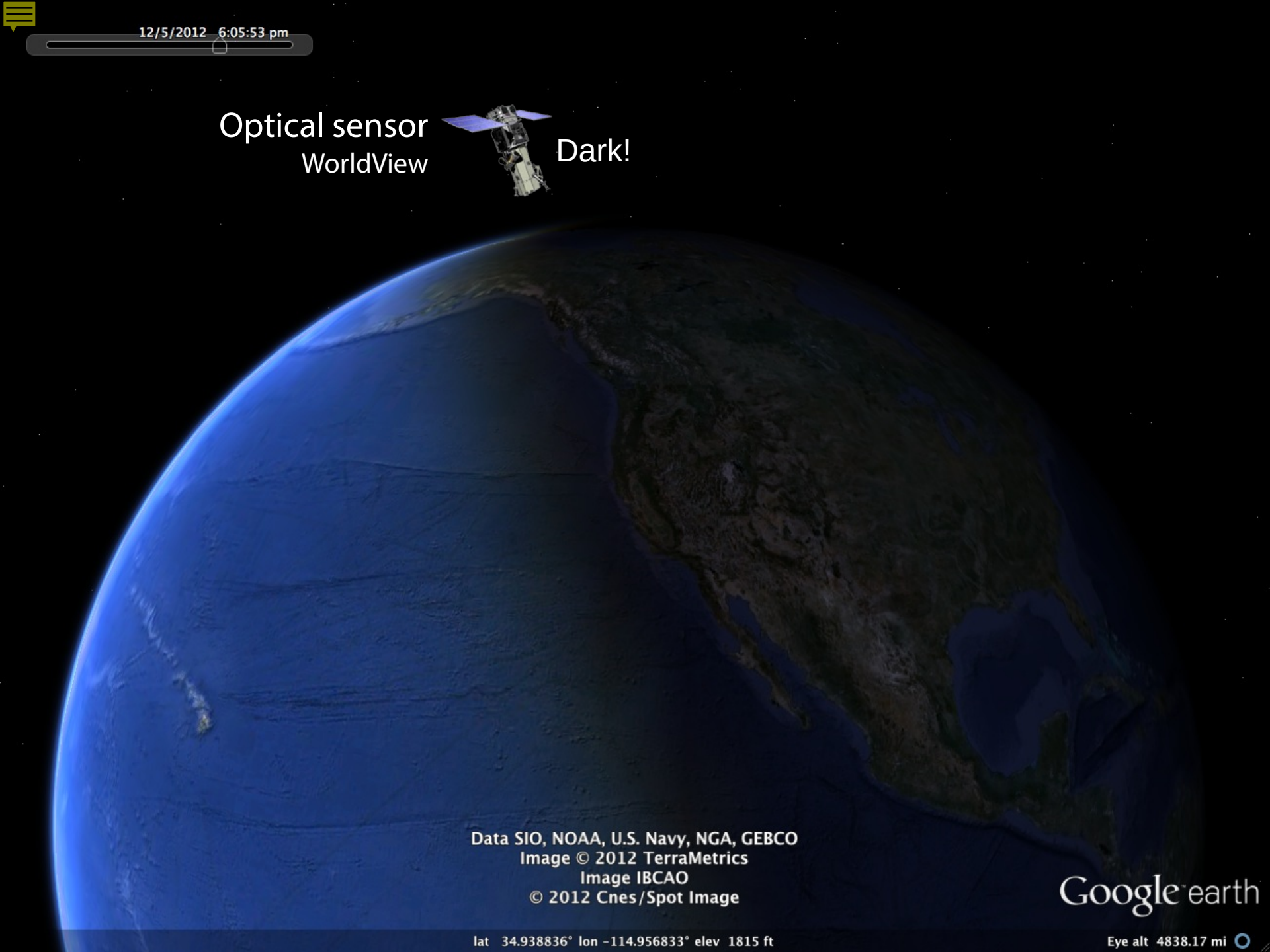
Cal EMA California Emergency Management Agency

"We have high hopes for ARIA", K. Saito, World Bank

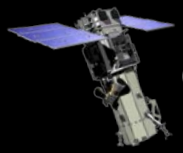
ARIA Projects 2014.01.22

ARIA-EQ (R&TD) is developing all connections in the blue regions, while ARIA-MH (AIST) will develop advanced functions for maturing the data system capabilities and enabling cloud-based hazard monitoring, data processing, management, and distribution. ARIA Co-Laboratory (PDF) is advancing low-latency GPS, optical satellite imagery and fault modleing integration.

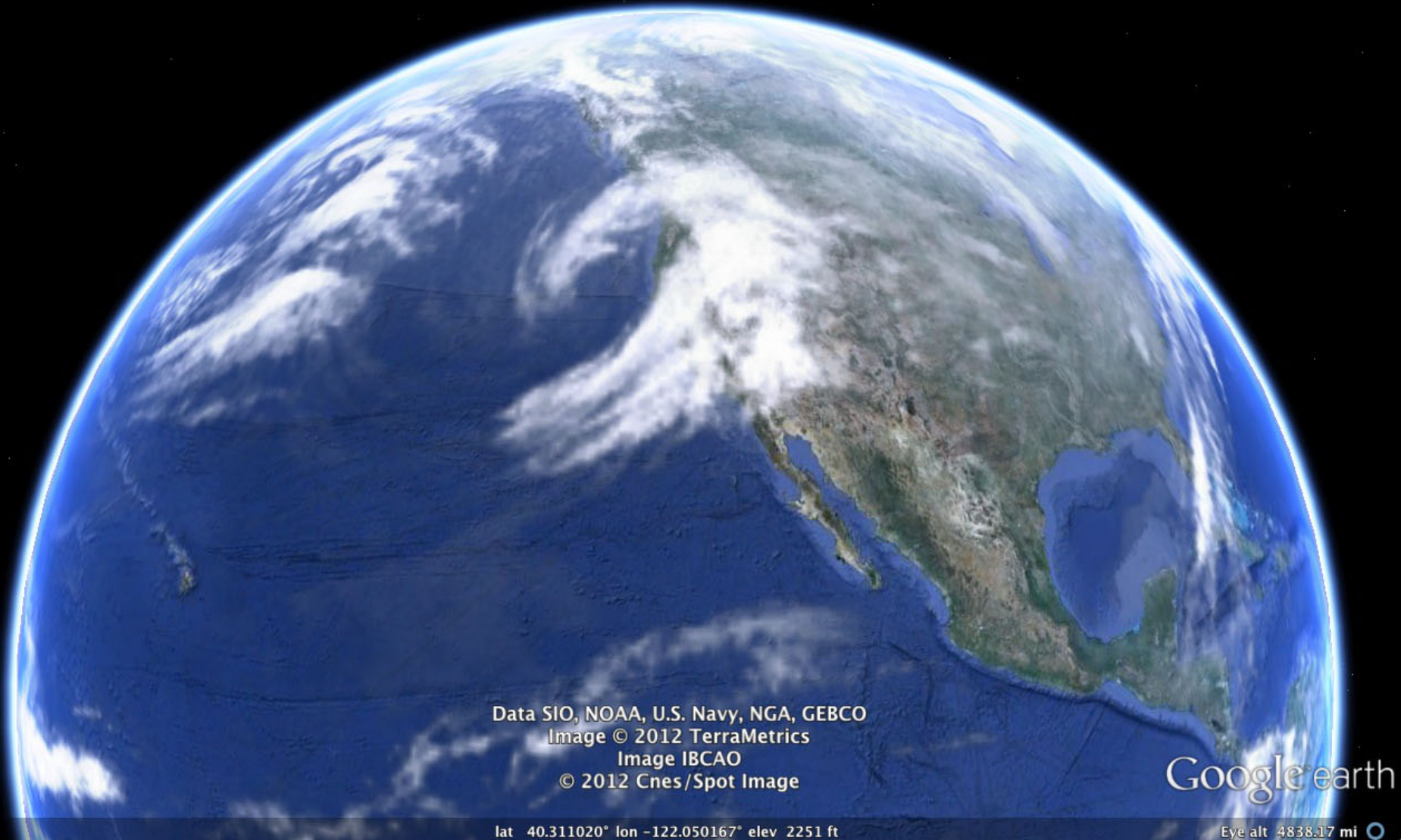



12/5/2012 6:05:53 pm
Optical sensor
WorldView
Dark!
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
Image IBCAO
© 2012 Cnes/Spot Image
Google earth
lat 34.938836° lon -114.956833° elev 1815 ft
Eye alt 4838.17 mi

Optical sensor
WorldView



Cloudy!



Radar sensor
US L-band Mission

Radar can “see” through clouds and at night.

Envisat (ESA)
C-band

COSMO-SkyMed (ASI) X-band

ALOS (JAXA)
L-band

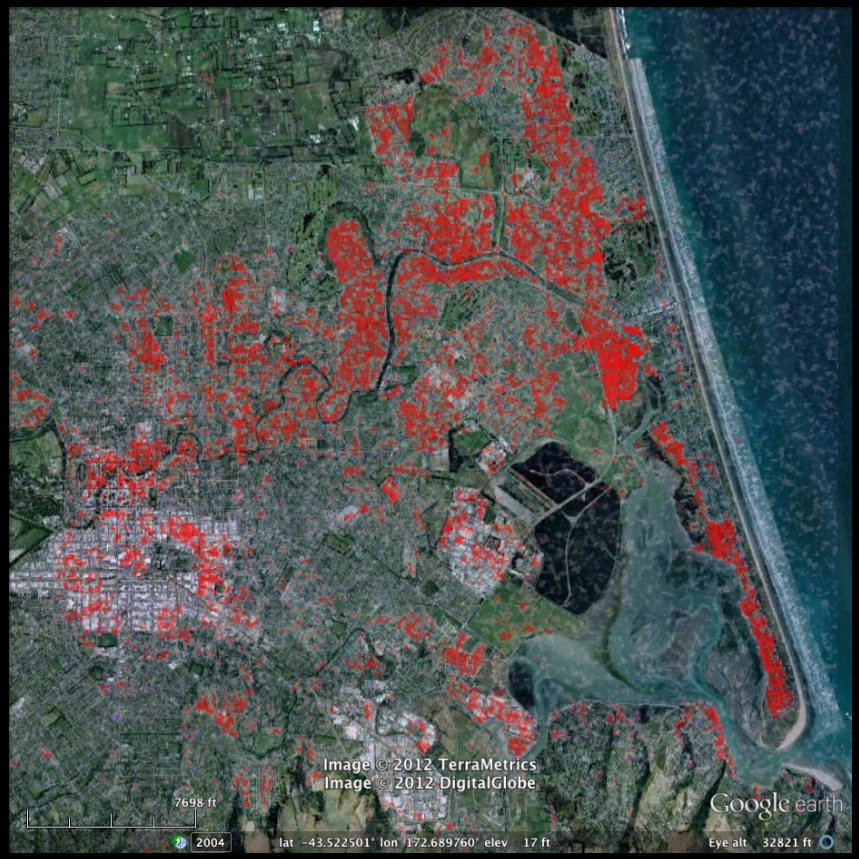
- 2011 M6.3 Christchurch Earthquake, New Zealand – building damage, liquefaction, cliff collapse (ALOS)
- 2011 M9.0 Tohoku Earthquake, Japan – building damage, floods (ALOS, Envisat)
- 2011 Kirishima Volcano Eruption – vocanic ashfall (ALOS)
- 2012 Hurricane Sandy, New York City – building damage (COSMO-SkyMed)
- 2013 Khartoum Floods, Sudan – COSMO-SkyMed
- 2013 Super Typhoon Haiyan – building damage (COSMO-SkyMed)
- 2013 Sardinia Floods, Italy (COSMO-SkyMed)

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image © 2012 TerraMetrics
lat 40.311020° lon -122.050167° elev 2251 ft
Google earth
Eye alt 4838.17 mi

First Test of Damage Proxy Map for a Natural Disaster

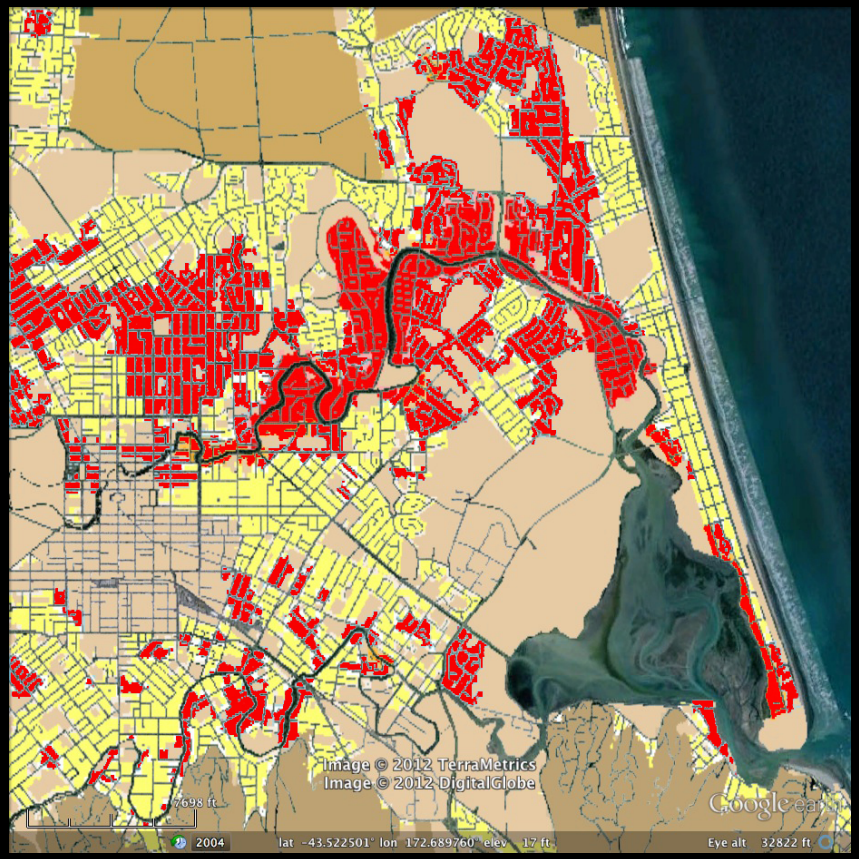
Feb 2011 M6.3 Christchurch Earthquake

Derived from Radar data acquired
3 days after the earthquake



Damage Proxy Map (ALOS PALSAR):
2010.10.10 – 2011.01.10 – 2011.02.25

Damage zone map based on house/land inspection
8 months after the earthquake



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

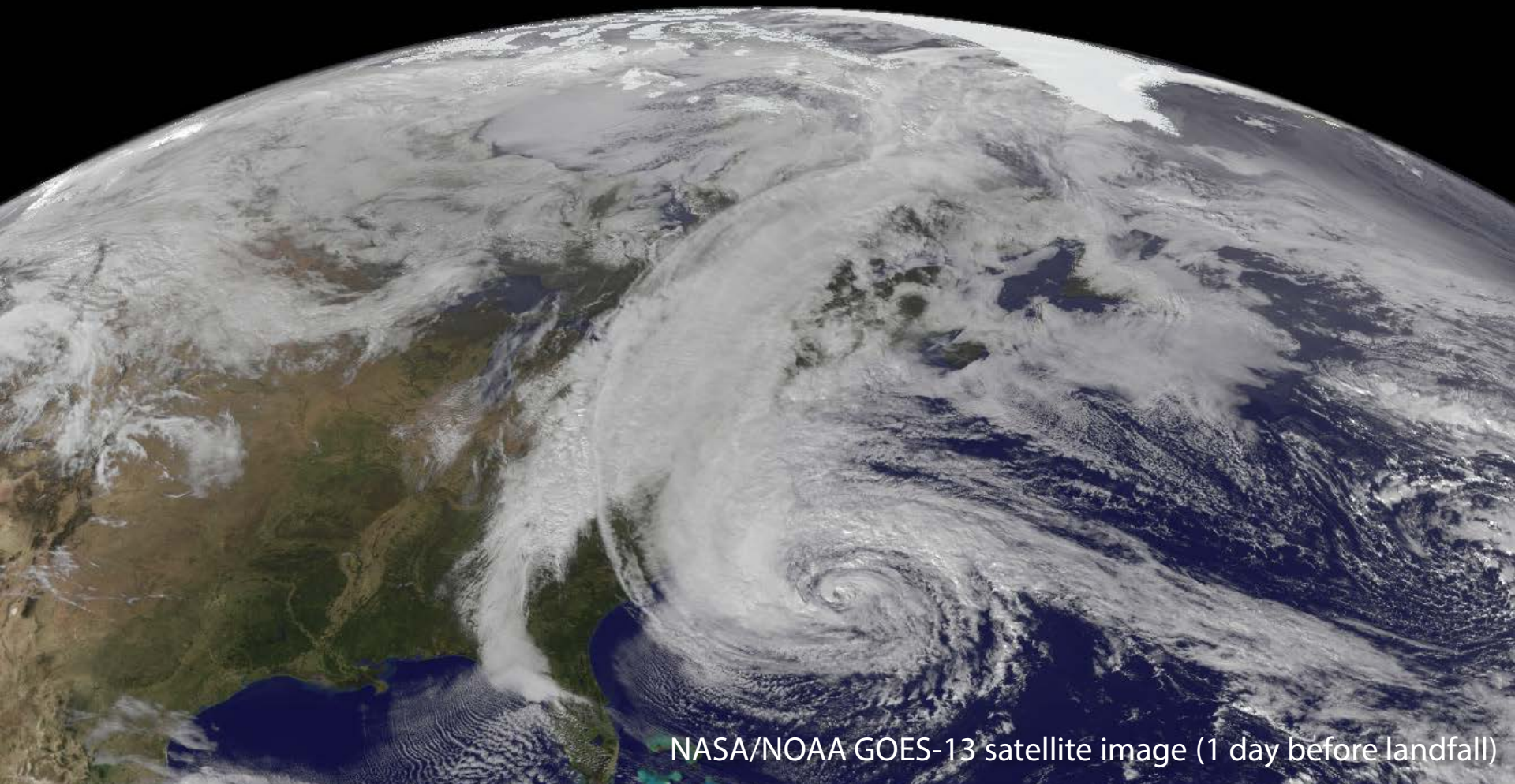
Original ALOS Data © JAXA, METI 2011

Hurricane Sandy Video from NASA/NOAA GOES-14 Satellite

Hurricane Sandy

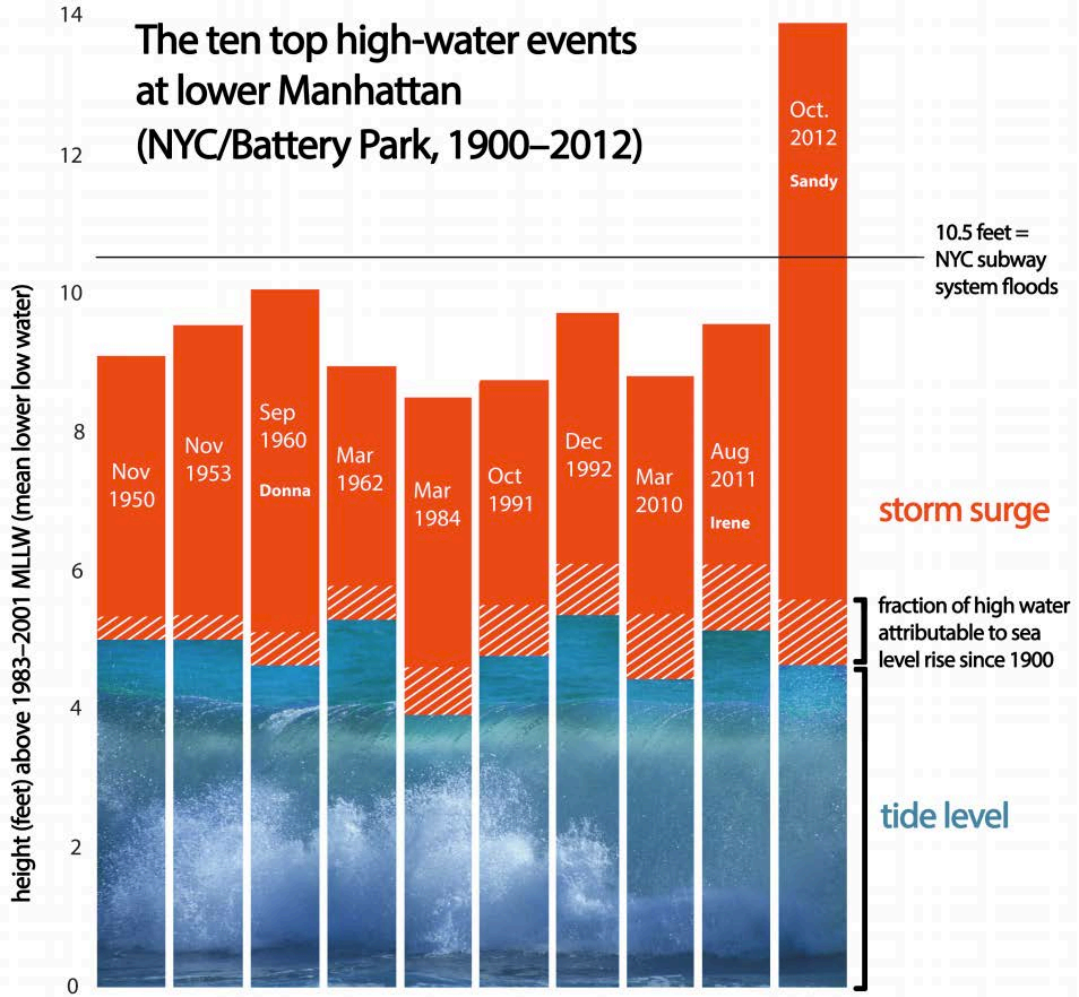
- Diameter 1600 km, Category 1 at landfall (2012-10-29 8PM EDT)
- Direct deaths: 147 (72 in the U.S.)
- ~650,000 houses damaged in the U.S.
- Damage: ~ $50 billion (2nd costliest next to Katrina)

Based on Hurricane Sandy Reports by National Hurricane Center and NOAA



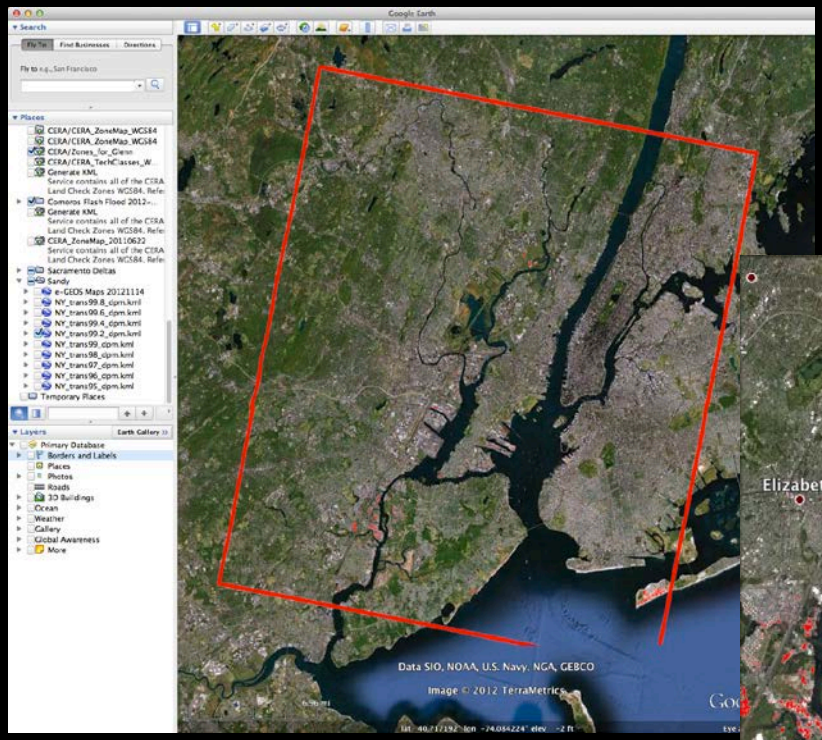
NASA/NOAA GOES-13 satellite image (1 day before landfall)

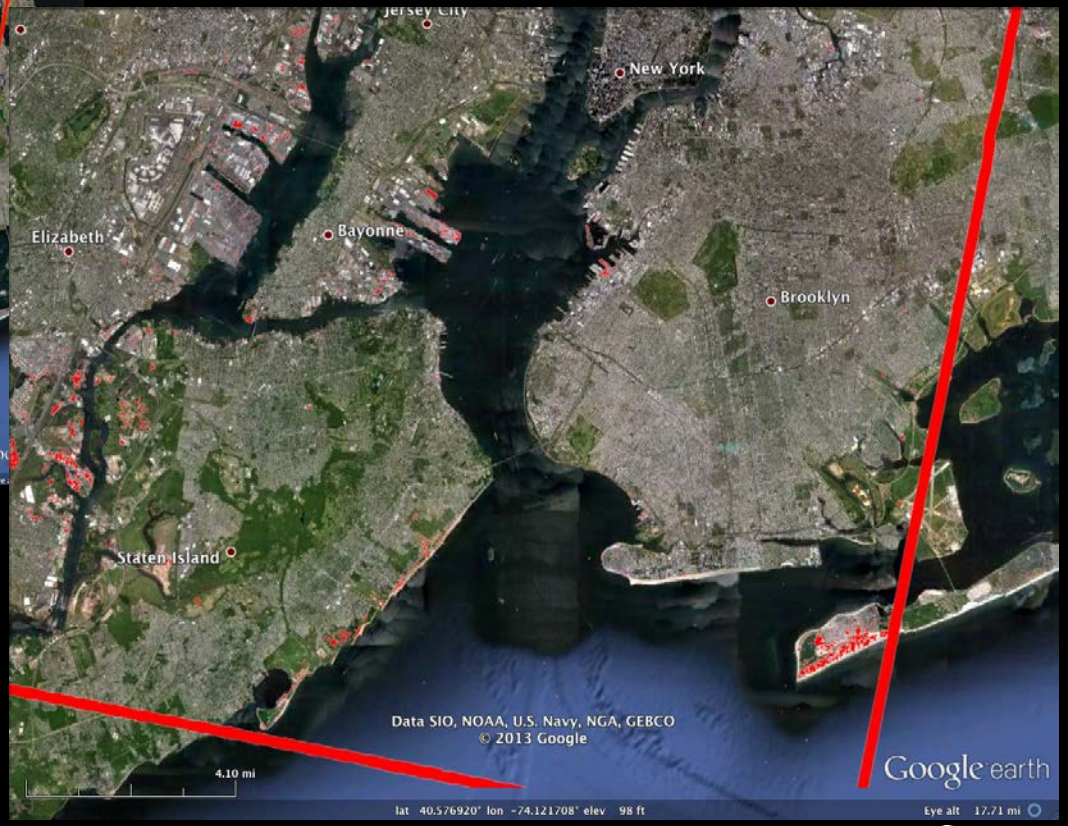
What made Sandy's surge so high?



Bob Henson, 2012

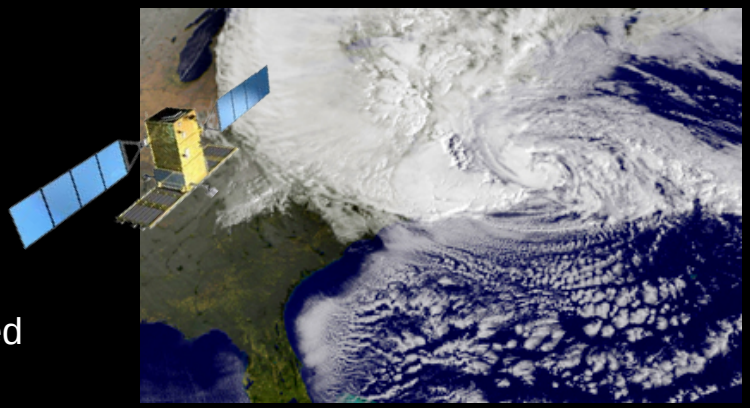
Damage Proxy Map v1 of New York City
Derived from COSMO-SkyMed Data



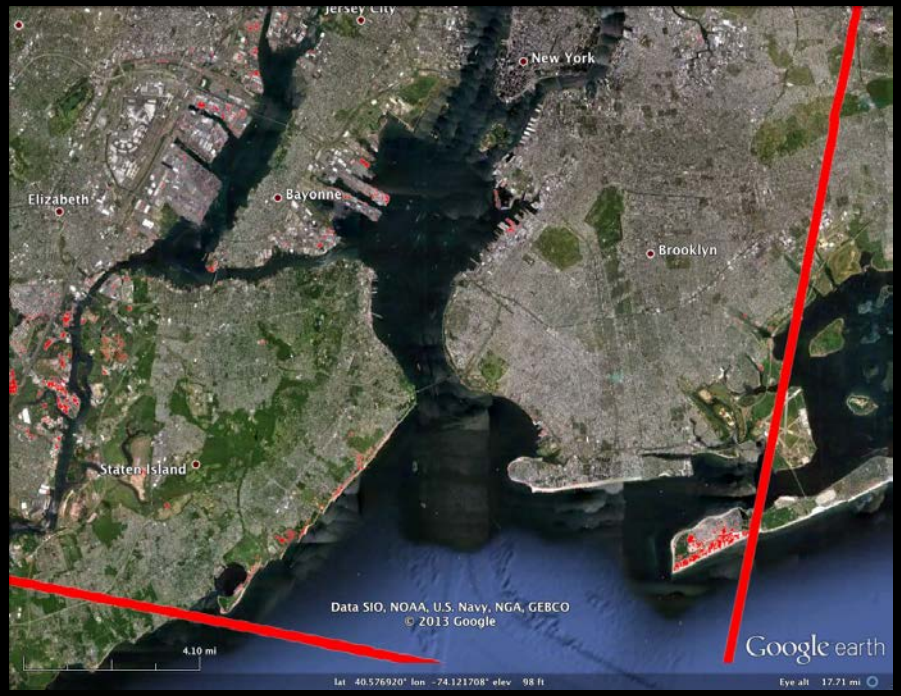


Original COSMO-SkyMed Data © ASI 2012

Hurricane Sandy Damage in New York City Imaged with COSMO-SkyMed and Mini-crowdsourcing



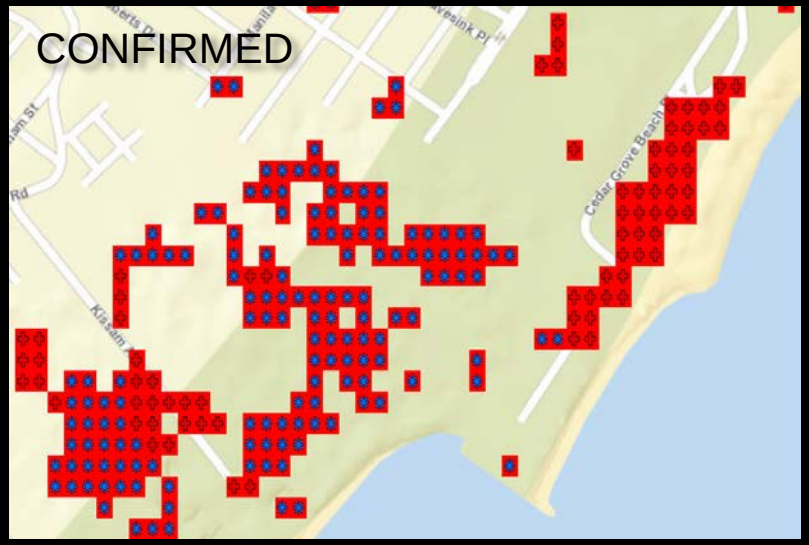
- 2012-10-29 8PM (EDT): Sandy landfall
- 2012-11-03 (Day 5): COSMO-SkyMed (X-band) data acquired
- 2012-11-09 (Day 11): Damage Proxy Map created
- 2012-11-13 (Day 15): Damage Proxy Map validated with 3 volunteers from GISCorps



Damage Proxy Map

Validation

False Positives – Vegetation Change



False Positives – Anthropogenic Change

DPM

2006-11-02

2012-05-26

2012-11-05

ARIA's Sandy Response Timeline Analysis

Data Acquisition
5 days

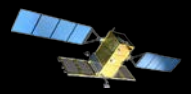
Discovery, Transfer, Processing
6 days

Validation
4 days

Sandy landfall
2012/10/29 8PM

Day 5

COSMO-SkyMed acquires data 11/3



Day 8

Data appear in web catalog

Day 9

ARIA downloads the data

ftp://

Day 11

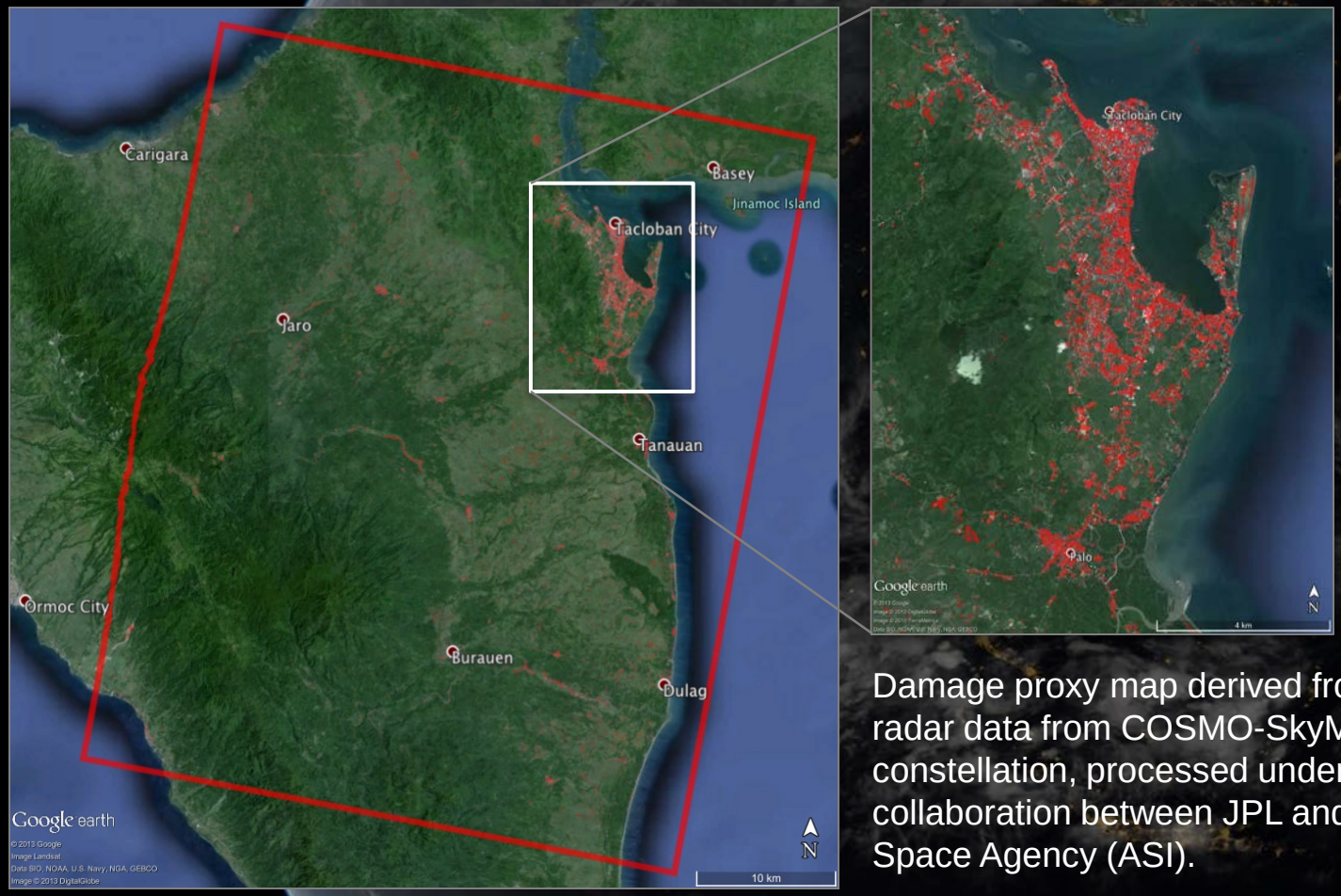
ARIA makes DPM

Day 15

DPM validation completed (GISCorps)

NASA · California Institute of Technology 1891 · asi agenzia spaziale italiana · GISCORPS URISA · ARIA JPL-Caltech

Damage Proxy Map of Tacloban Area, Philippines hit by Super Typhoon Haiyan

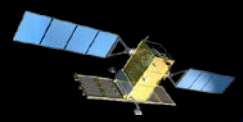


Damage proxy map derived from X-band radar data from COSMO-SkyMed constellation, processed under a joint collaboration between JPL and the Italian Space Agency (ASI).

ARIA's Haiyan Response Timeline

"The biggest challenge is really just the scope of the damage."

Nancy Lindborg, assistant administrator for humanitarian assistance at the USAID, on LA Times on Nov 26 (Day 18)

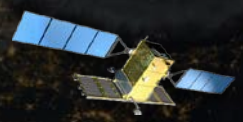


COSMO-SkyMed acquires data 8/19

Day -81
09:00

Day 0
00:00

Haiyan hits Philippines
2013/11/08 00:00 UTC



COSMO-SkyMed acquires data 11/11

Day 3
09:00

ftp://

ARIA accesses the data

Day 3
14:00

ARIA produces DPMs 2013/11/11 (11 hours after data acquisition)

Day 3
20:00

time

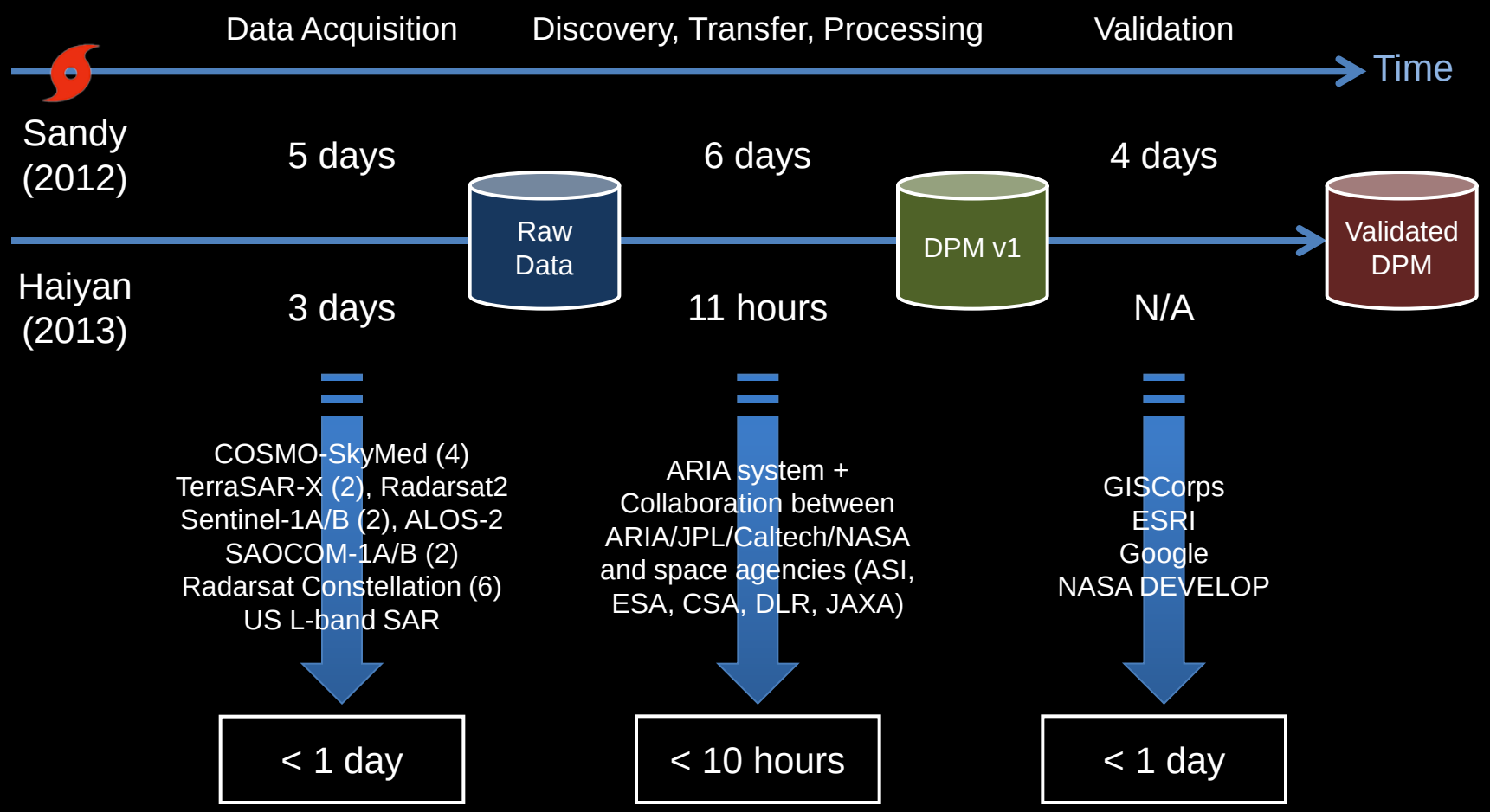
Day 2
02:00

GeoEye-1 acquires data 11/10

Day 3

Copernicus EMS produces damage grading maps of selected areas 2013/11/11

DPM Latency Reduction



Validation Tools for Volunteers

Web Interface (current polygon)

Web Interface (false positive)

Web Interface (true positive)

Web Interface (uncertain)

Web Interface (true positive)

Web Interface (next polygon)

Mobile Interface (before)

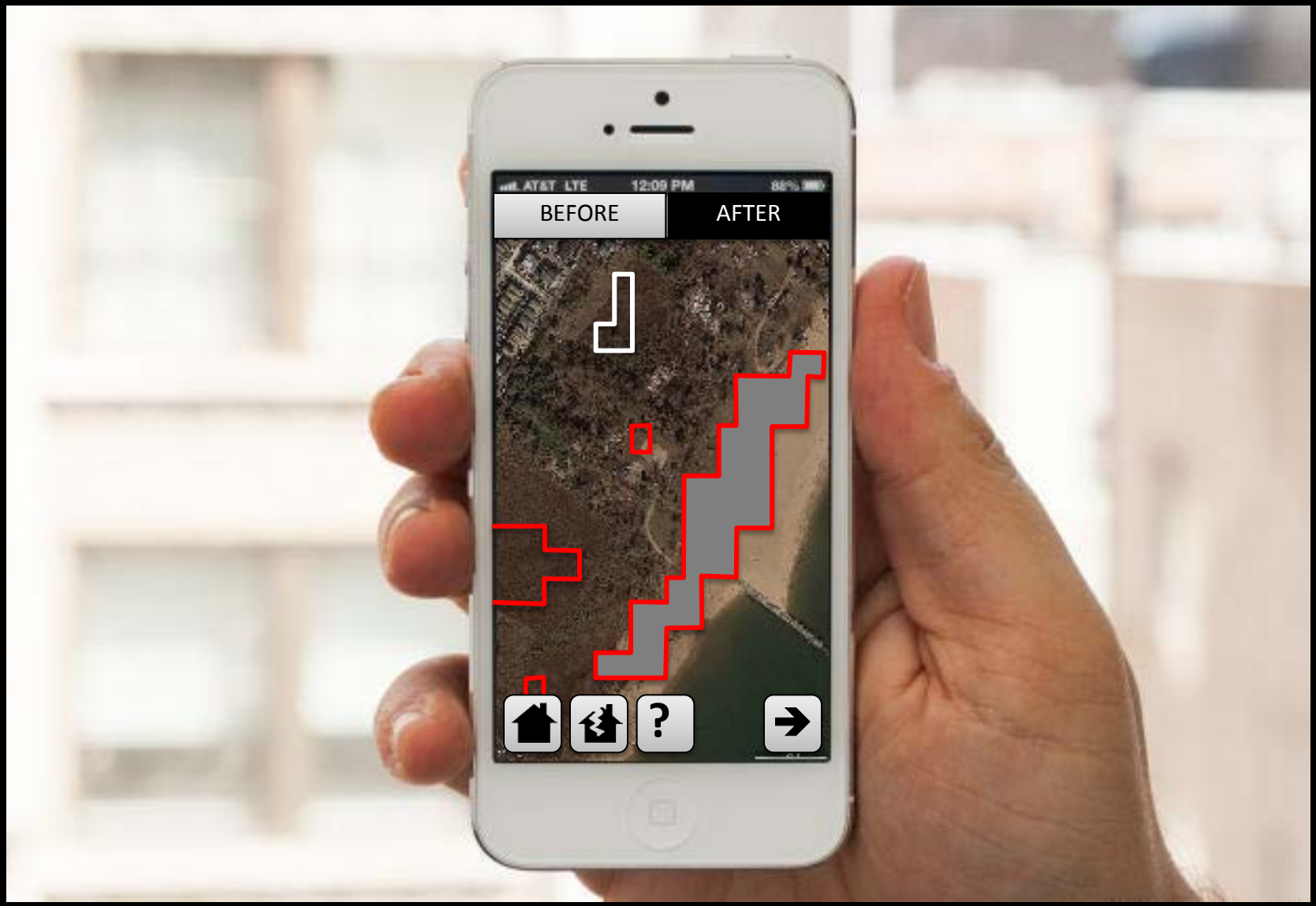
Mobile Interface (after)

Mobile Interface (false positive)

Mobile Interface (true positive)

Mobile Interface (uncertain)

Mobile Interface (next polygon)



Conclusions

Radar sensors have all-day and all-weather imaging capability, especially useful for weather events. Future imaging radar satellites will visit disaster sites on Earth within 24 hours after a disaster event. The expected data acquisition latency in 2015-2020 is 8~15 hours.

A prototype algorithm for damage proxy map was developed and tested with L/C/X-band radar data. The algorithm is under development with NASA's Applied Sciences Program fund.

ARIA team at JPL/Caltech, in collaboration with the Italian Space Agency, responded to Hurricane Sandy and produced a damage proxy map of New York City, derived from X-band COSMO-SkyMed data. The map was then validated with a mini crowdsourcing organized by the GISCorps. 15 days were spent on the end-to-end all human-in-the-loop response, including 4 days of validation.

We also responded to Super Typhoon Haiyan and produced a damage proxy map of Tacloban area in the Philippines using COSMO-SkyMed data*. The total latency until the production of the DPM was 3 days.

Simple and intuitive web/mobile tools are required for rapid validation. A proof-of-concept is being developed with students supported by NASA's DEVELOP program.

* COSMO-SkyMed (CSK) data provided as part of a JPL-Caltech – Center for Earth Observations (CIDOT), Italian Space Agency (ASI) technical collaboration (CSK data © 2013 ASI).

Copyright 2014. All rights reserved.