Radar Sees Through Clouds
We Map Disasters on the Cloud

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2. Earth Observatory of Singapore, Nanyang Technological University
3. California Institute of Technology
4. Academia Sinica, Taipei

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Jet Propulsion Laboratory
California Institute of Technology

Background: 2013 EUMETSAT
https://www.flickr.com/photos/eumetsat/10726056545/in/photostream/

ARIA JPL-Caltech

JPL

Integrating
Space Geodesy
Seismology
Modeling

Seismological Laboratory
California Institute of Technology

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

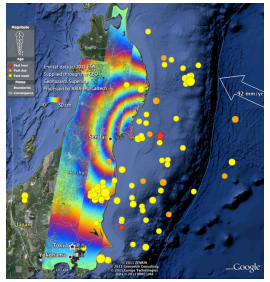
Radar Sensors

GPS Networks

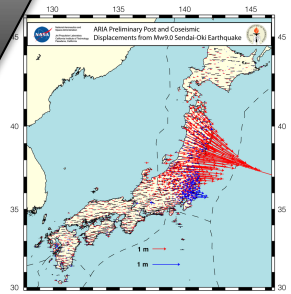
Seismic Networks

Optical Sensors

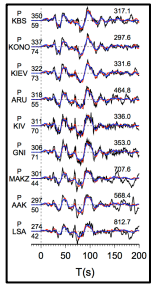
Automated Data Collection & Processing



Radar



GPS

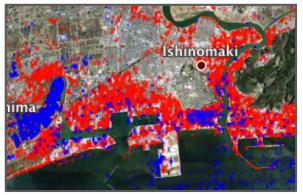


Seismology

amazon web services

Monitoring & Near Real-Time Assessment

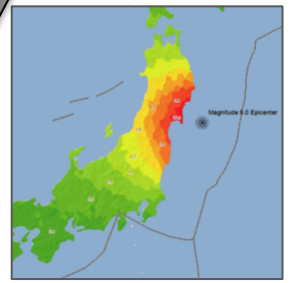
Potential Partners



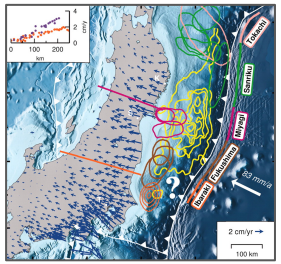
Building Damage & Inundation

"This is exactly the kind of product we are looking for."

Anne Rosinski
Calif. Geol. Survey



Permanent Ground Deformation

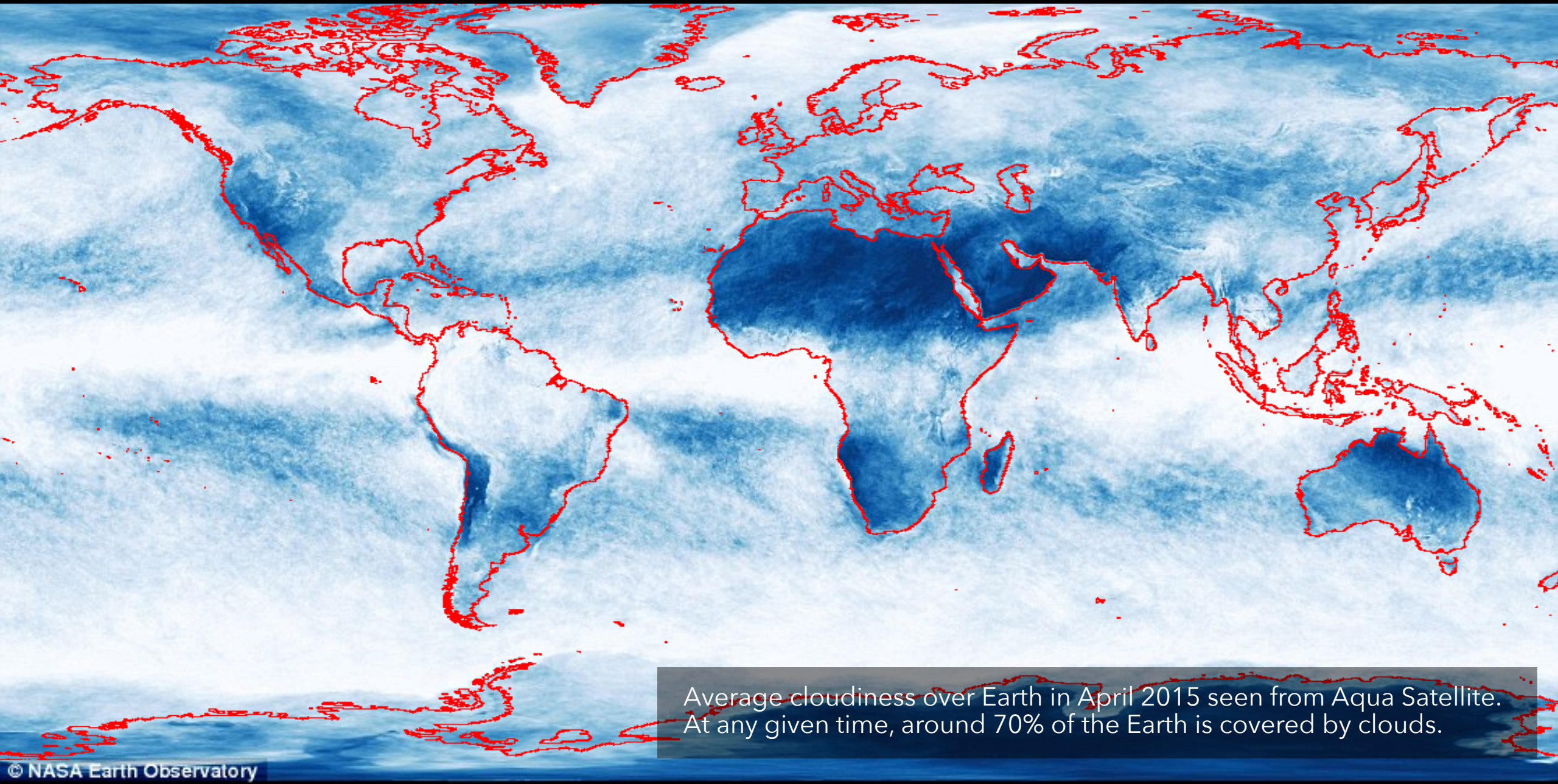


High-Resolution Hazard Assessment from Fault Models

"We have high hopes for ARIA."

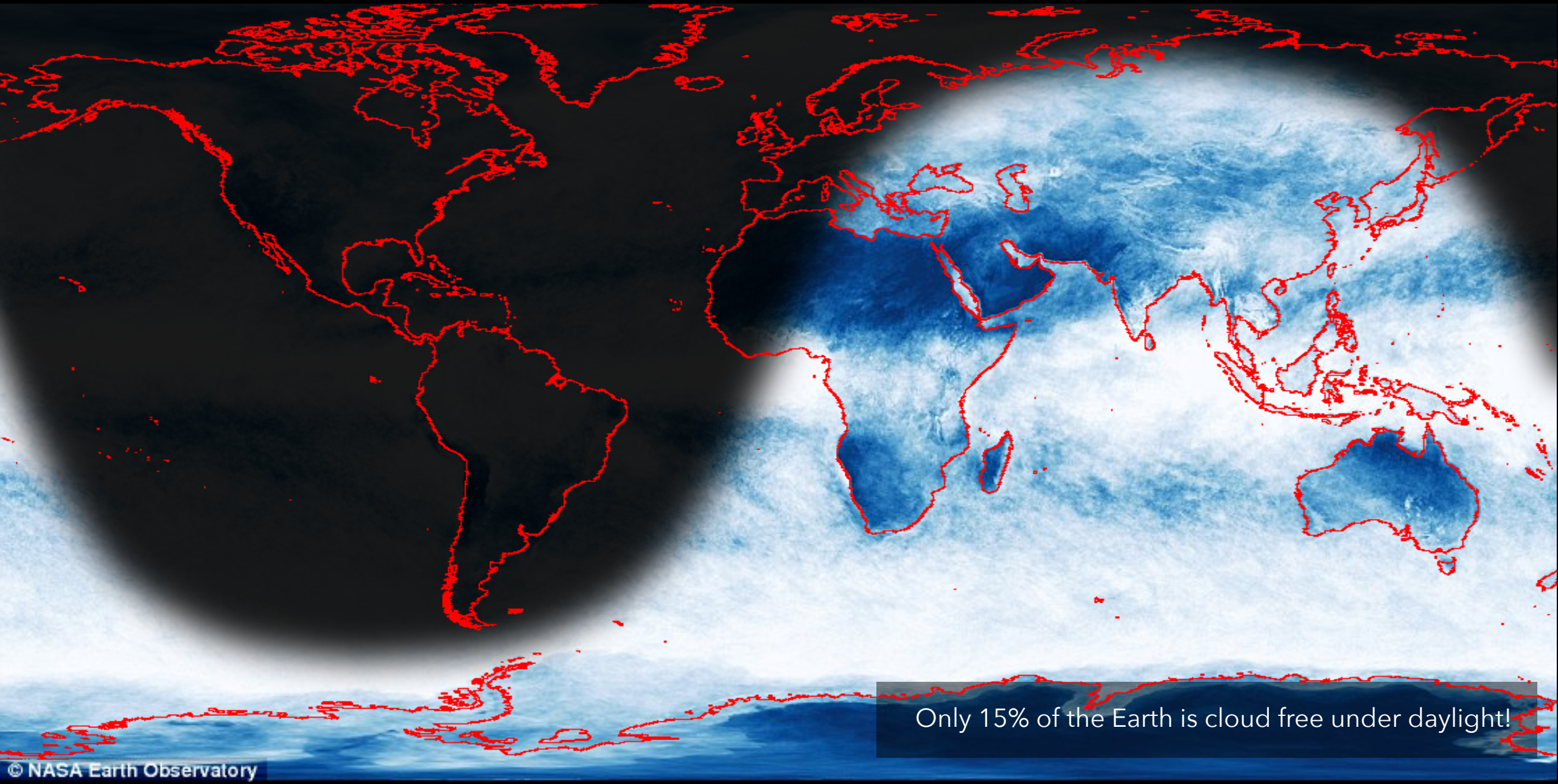
Keiko Saito
World Bank

SAR data is valuable for rapid disaster mapping

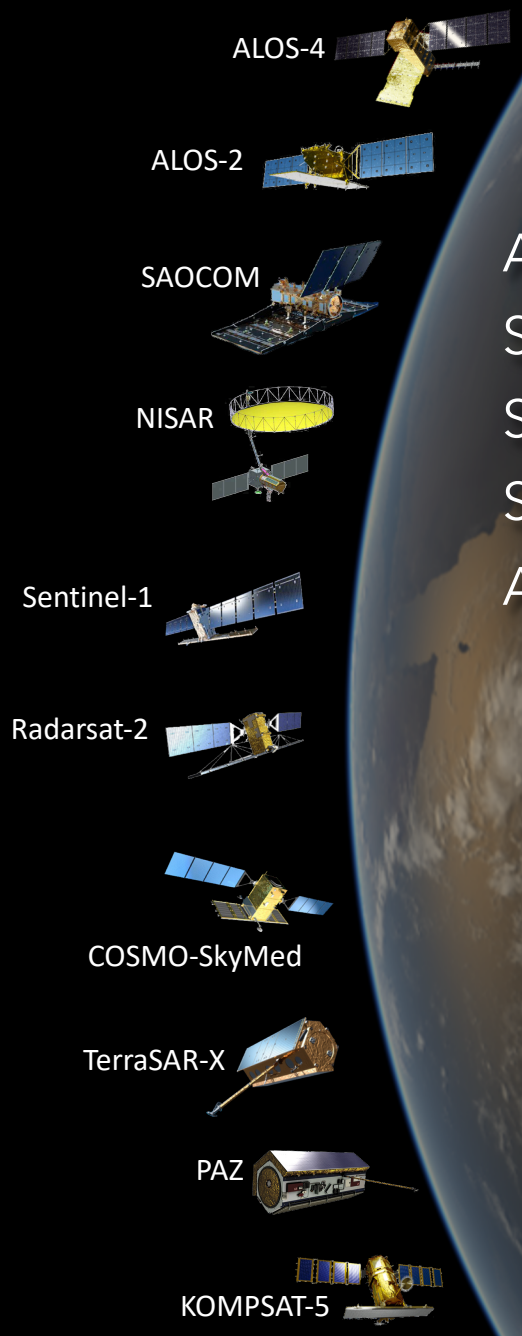


Average cloudiness over Earth in April 2015 seen from Aqua Satellite.
At any given time, around 70% of the Earth is covered by clouds.

SAR data is valuable for rapid disaster mapping



International SAR Satellites Overpass Latency



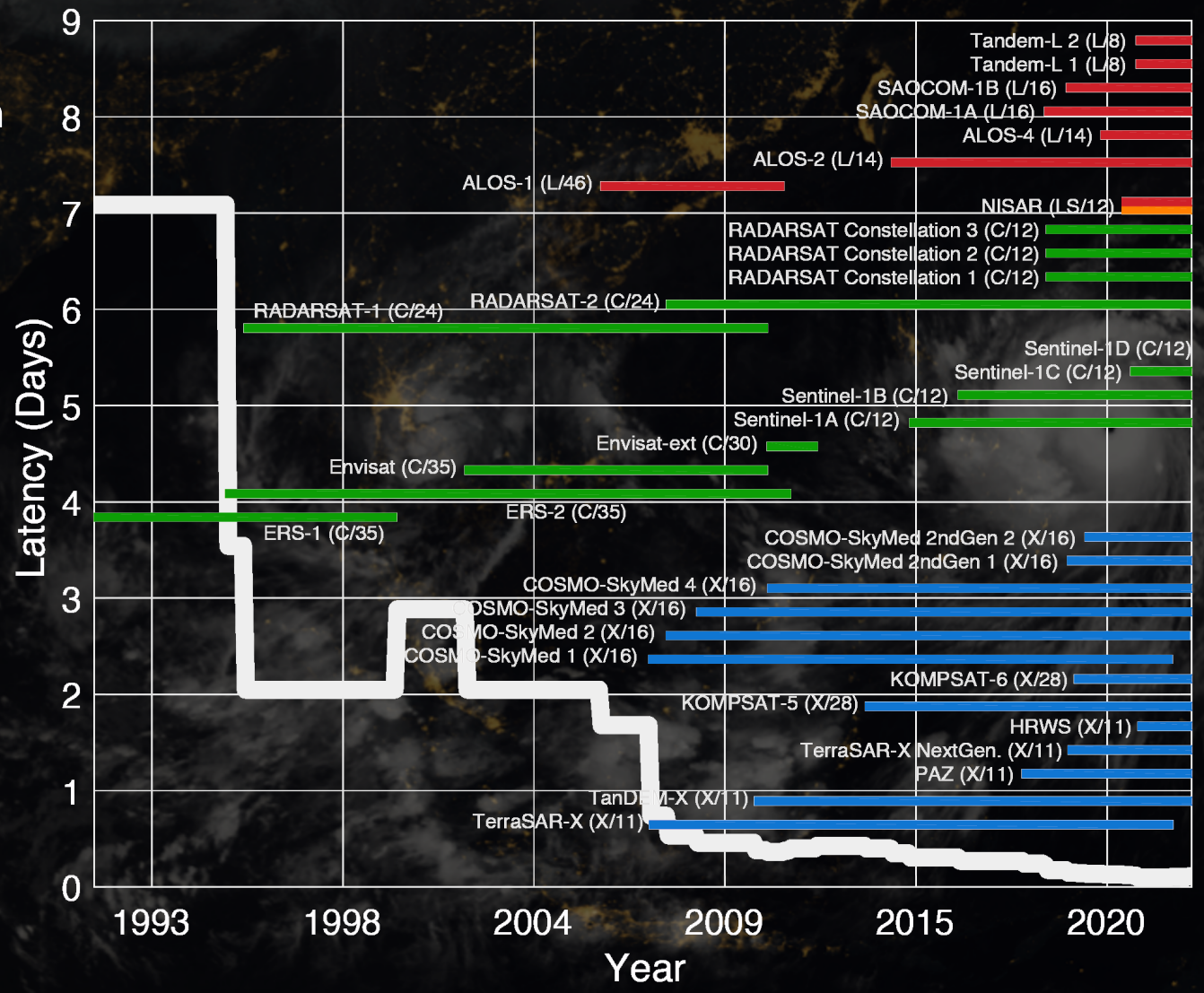
All missions: 6 h

S1 & A2 & CSK: 10 h

S1 & A2: 20 h

S1: 30 h

A2: 2.8 days

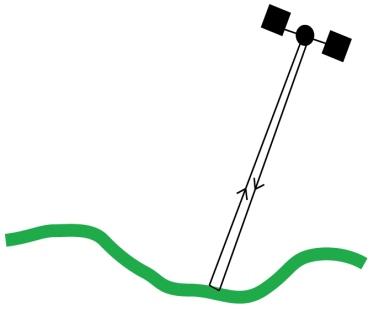


Can we “translate” what RADAR sees <u>accurately</u> and <u>rapidly</u> enough into what we would see on the ground?

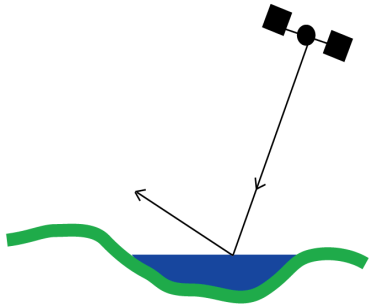
Introduction to flood mapping with SAR

- Flood Proxy Maps (FPMs) are created using SAR amplitude differences.

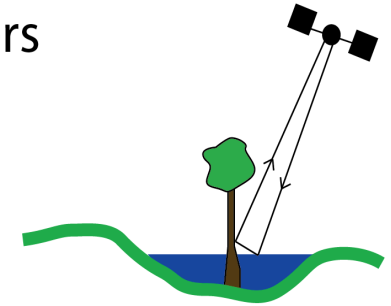
- How the amplitude changes during a flood event is dependent on land cover. Sometimes pixels get brighter and sometimes darker.



In dry conditions, the radar wave is reflected back to the satellite.



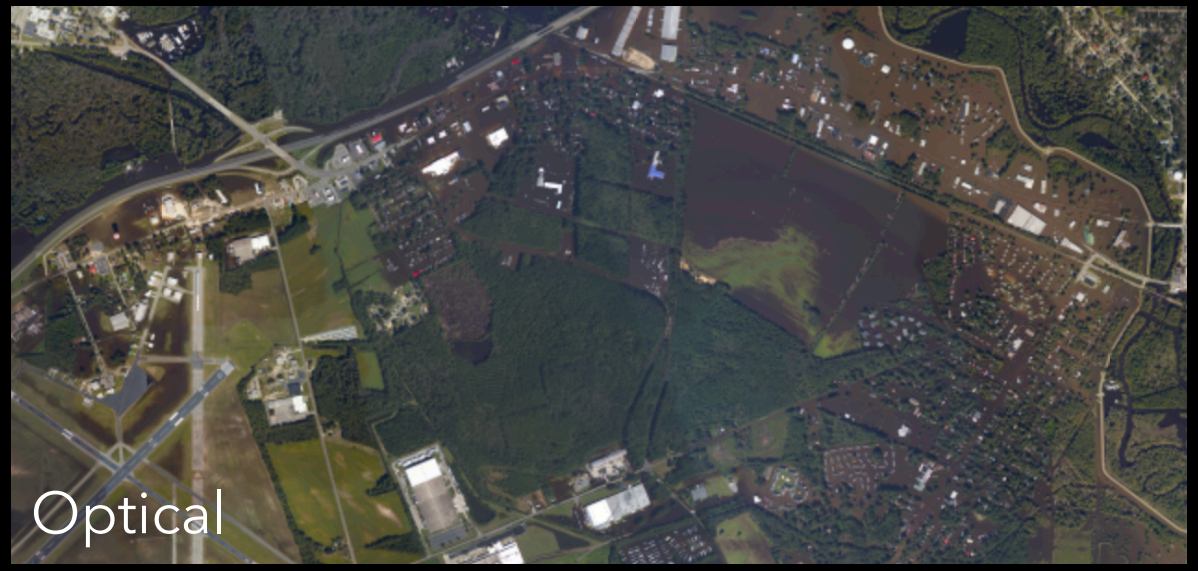
Open flood waters reflect the signal away from the satellite.

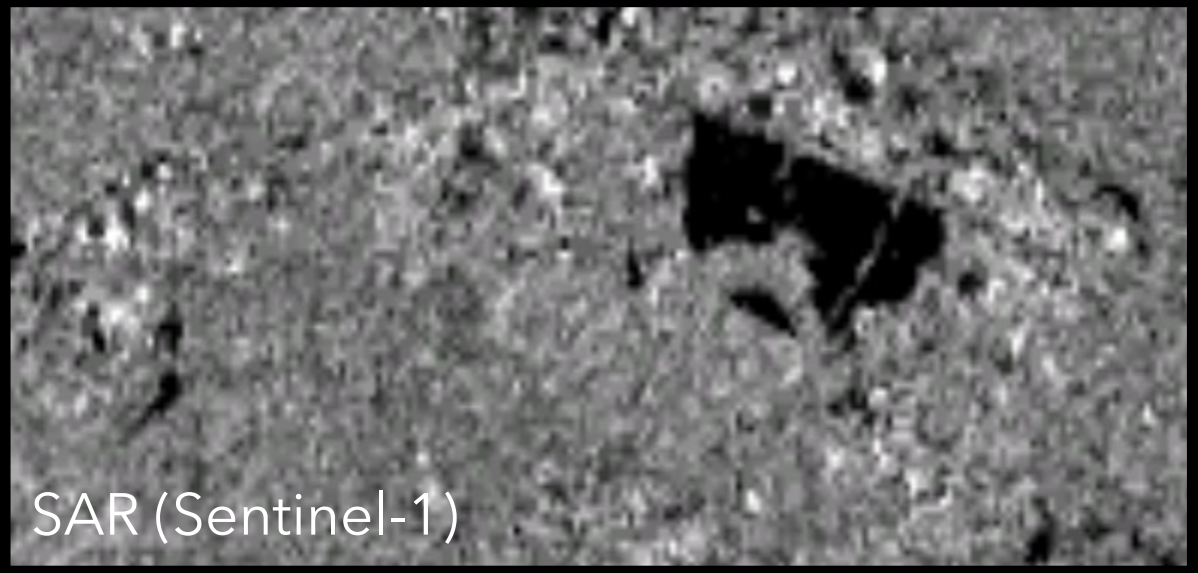


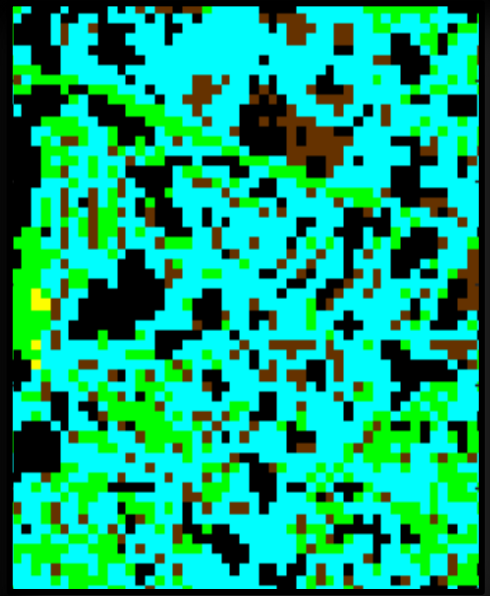
How the signal amplitude changes depends on surface features.

Figure by Emma Hill

2016 Hurricane Matthew, Lumberton, North Carolina





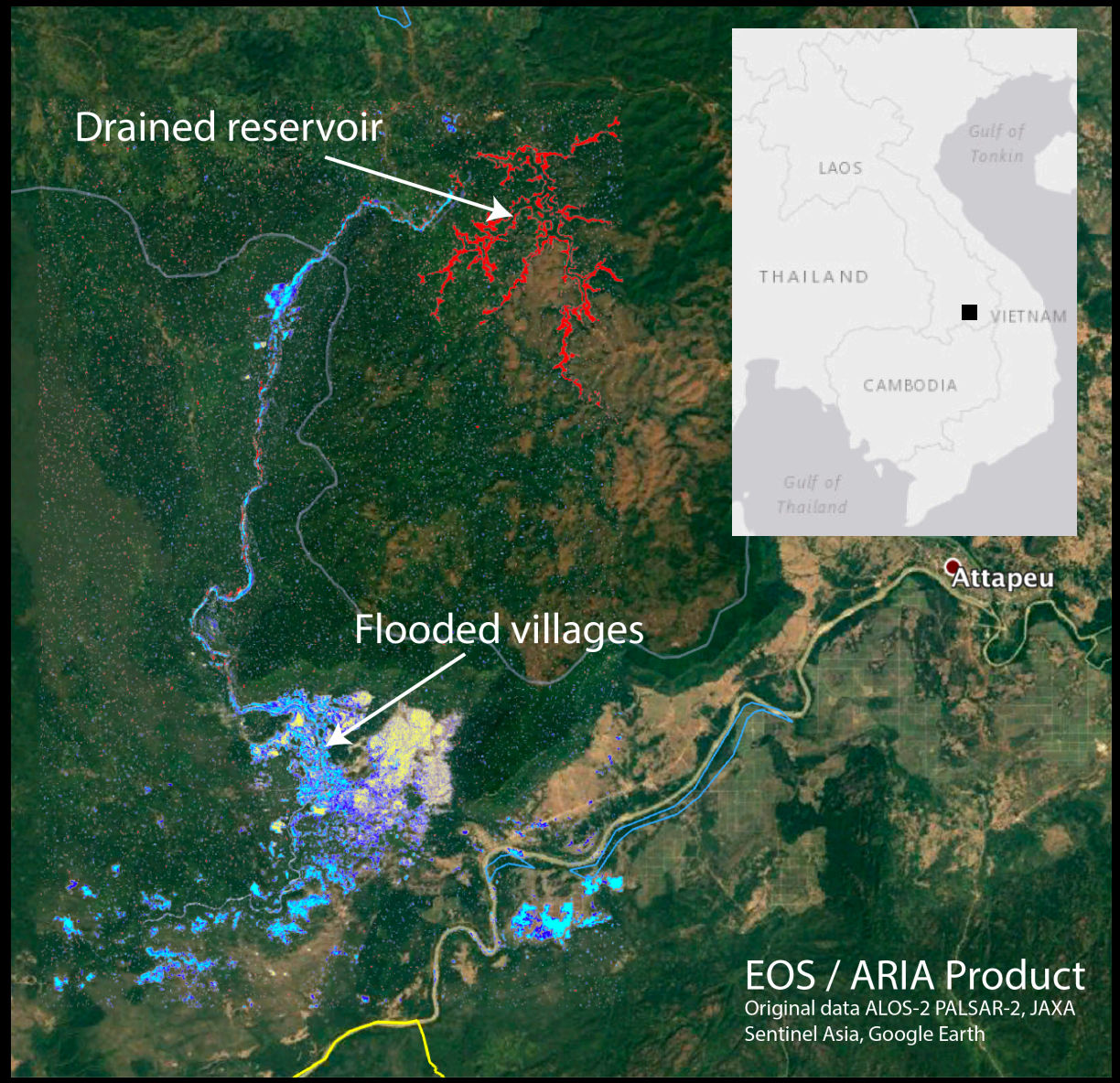


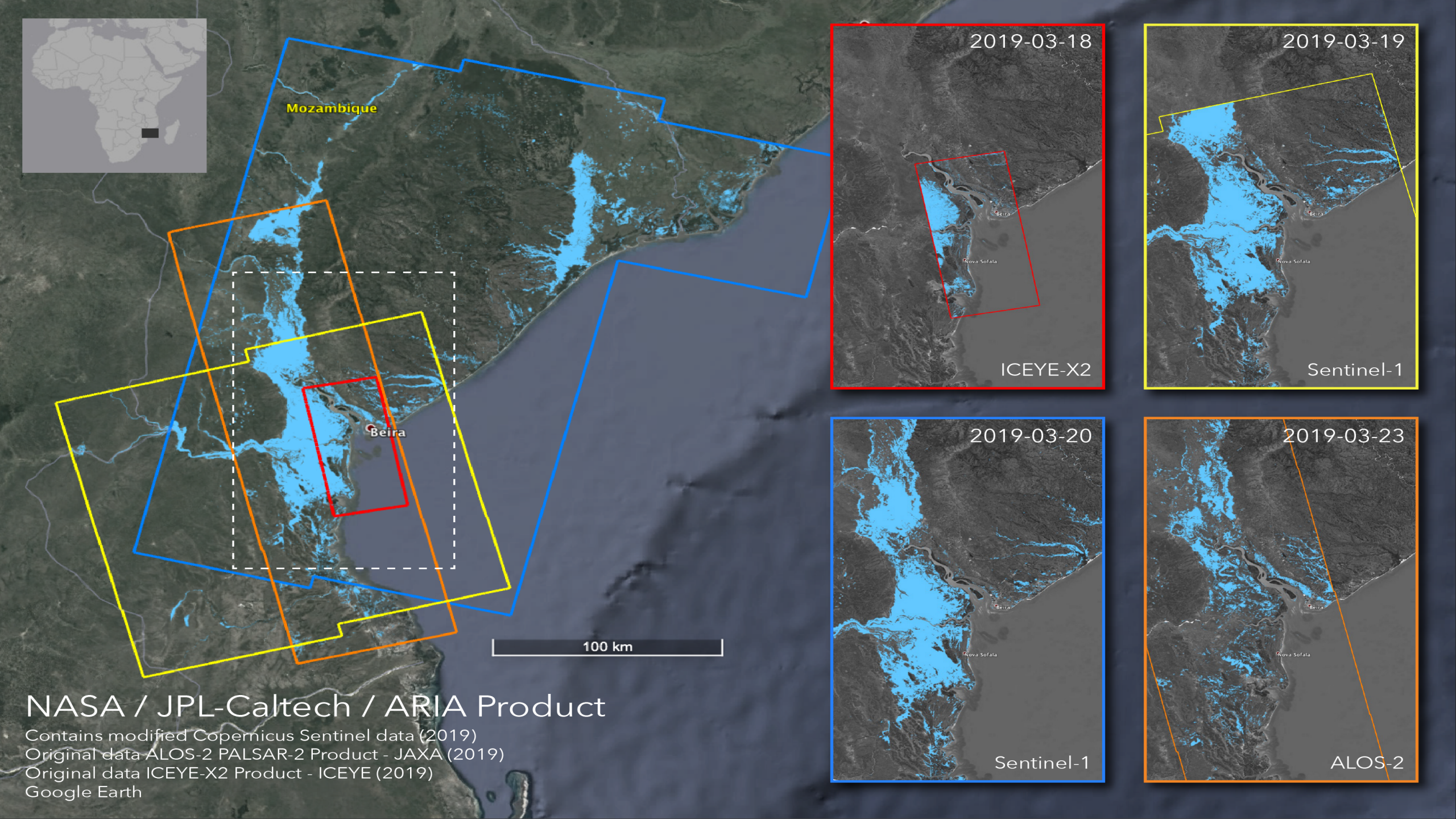
- Open water mapping straightforward
- Urban flood mapping is challenging
- Multitemporal SAR analysis improved accuracy by 143%
- Deep learning is being explored

- This Flood Proxy Map shows flood extent for the July 2018 Laos floods, which occurred after a dam collapsed.

- Red pixels: Wet to dry
  Blue pixels: Dry to wet
  Yellow pixels: Uncertain

by Nina Lin

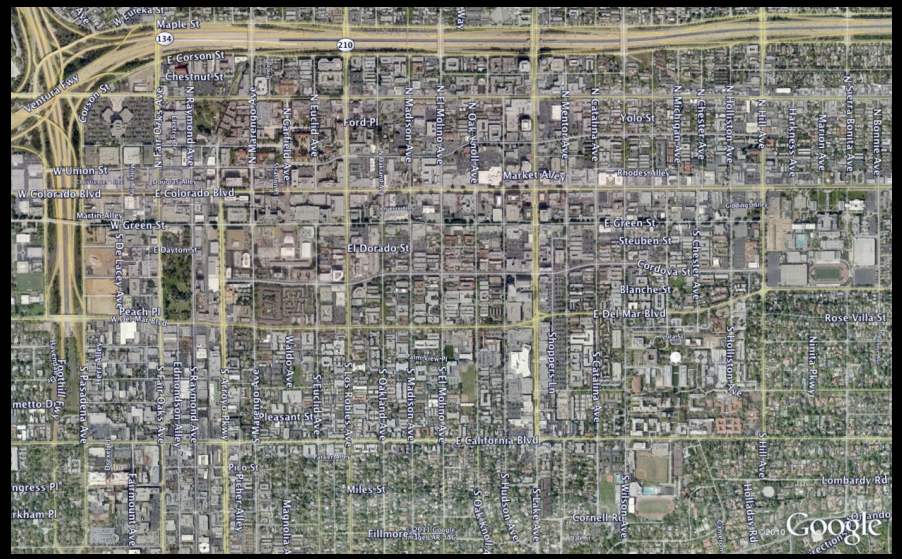


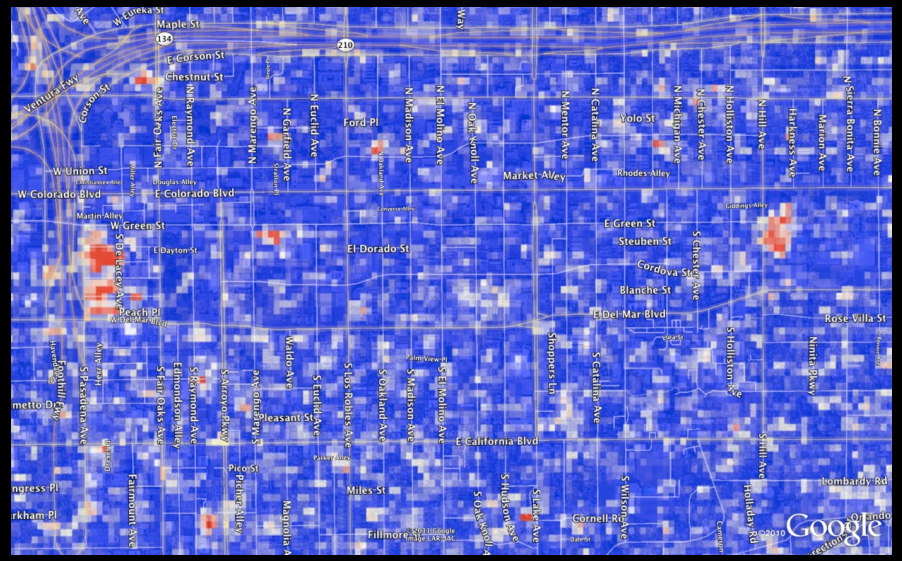


NASA / JPL-Caltech / ARIA Product

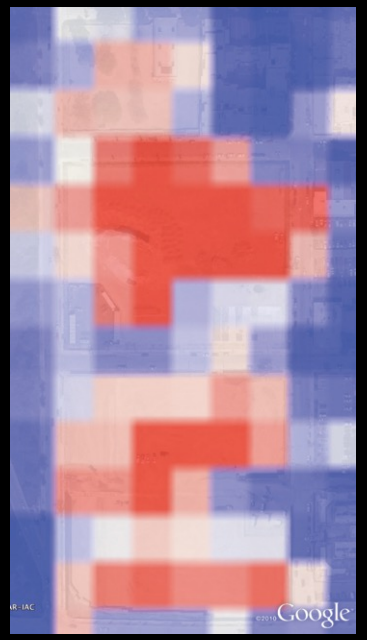
Contains modified Copernicus Sentinel data (2019)
Original data ALOS-2 PALSAR-2 Product - JAXA (2019)
Original data ICEYE-X2 Product - ICEYE (2019)
Google Earth

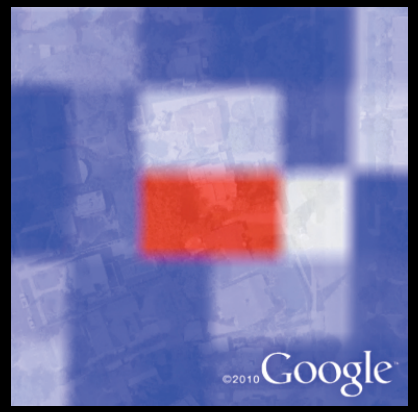
“Controlled” Experiment in Pasadena



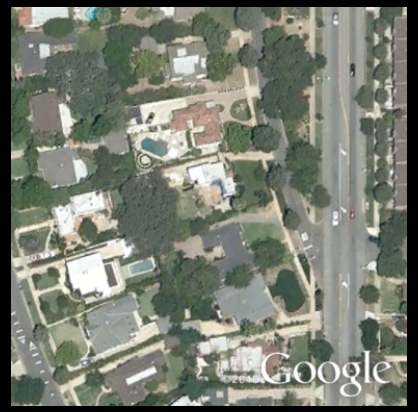


Original ALOS PALSAR Data © JAXA, METI 2008

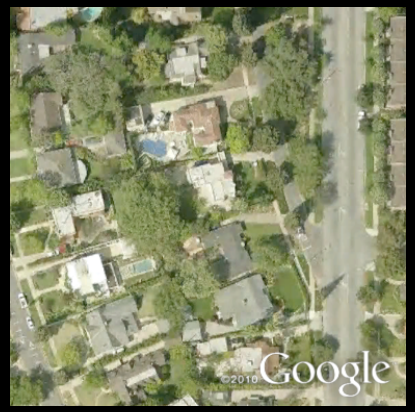




DPM



2007.10.23



2008.01.09

185 people killed

Over 1000 buildings destroyed

US $30+ billion damage

Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct

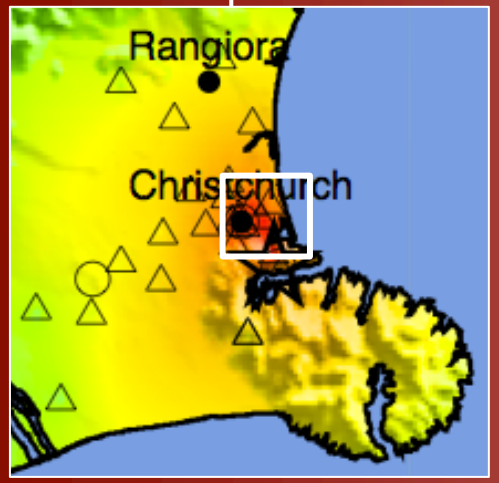
M6.3
Chch EQ

+ 3 days: ALOS acquires data

+ 4 months

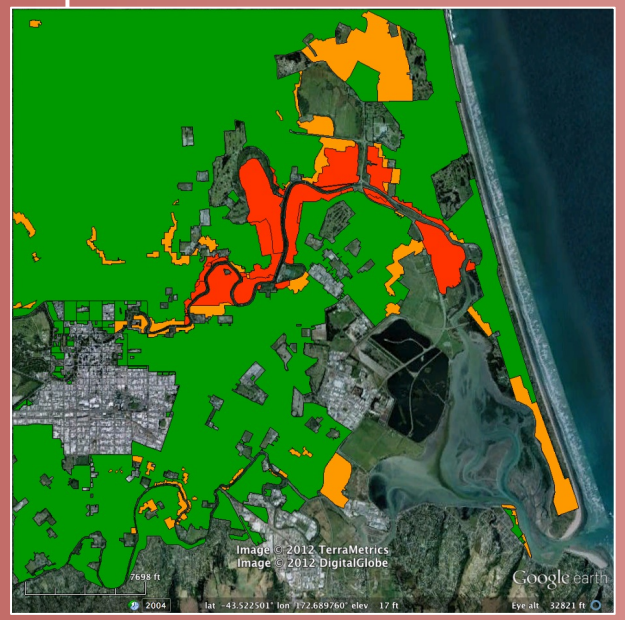
+ 8 months

+ 20 min



Multiple versions of Shakemap released
(USGS NEIC)

DPM from PALSAR data
(ARIA)



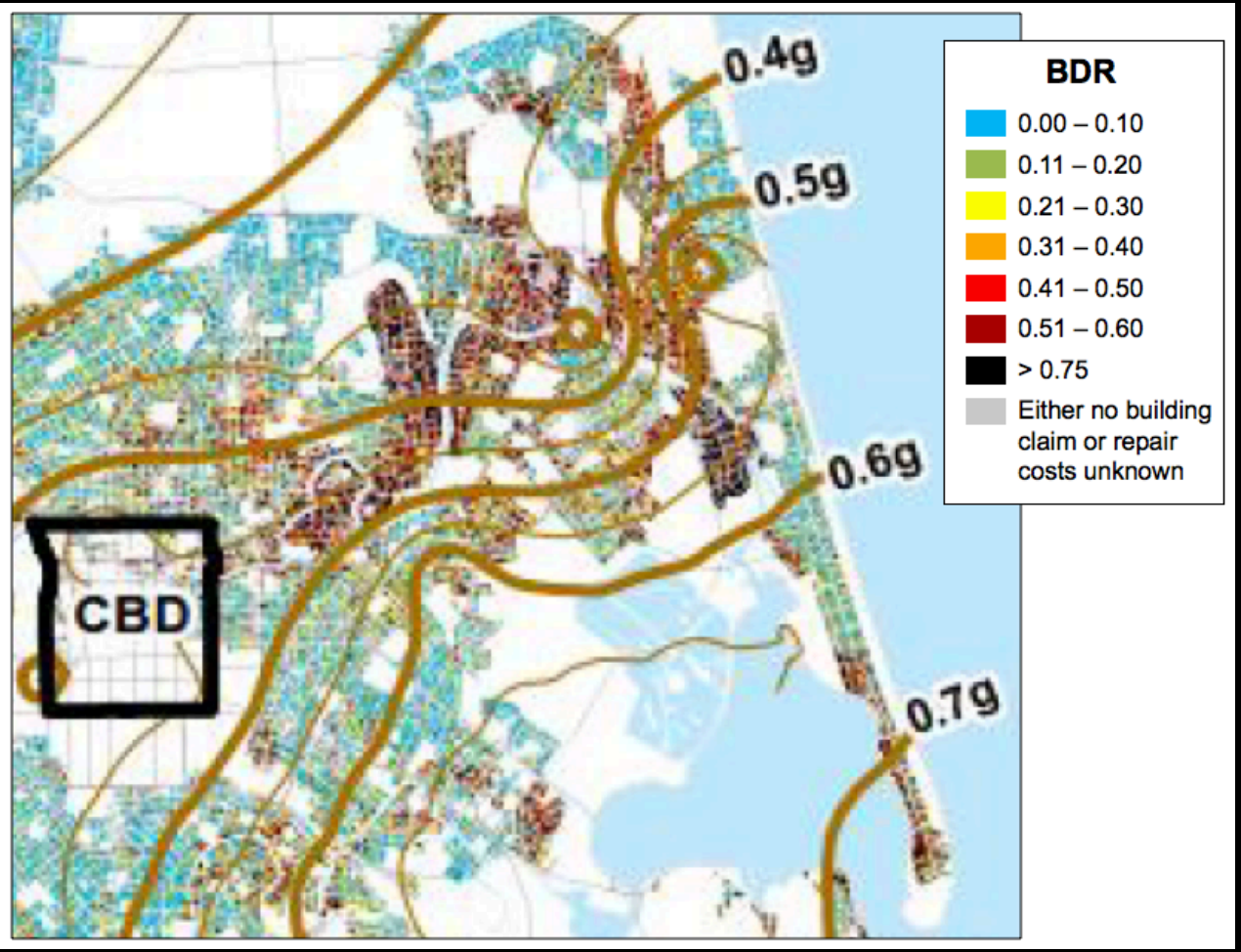
Official damage map
released based on
ground observations
(NZ Government)

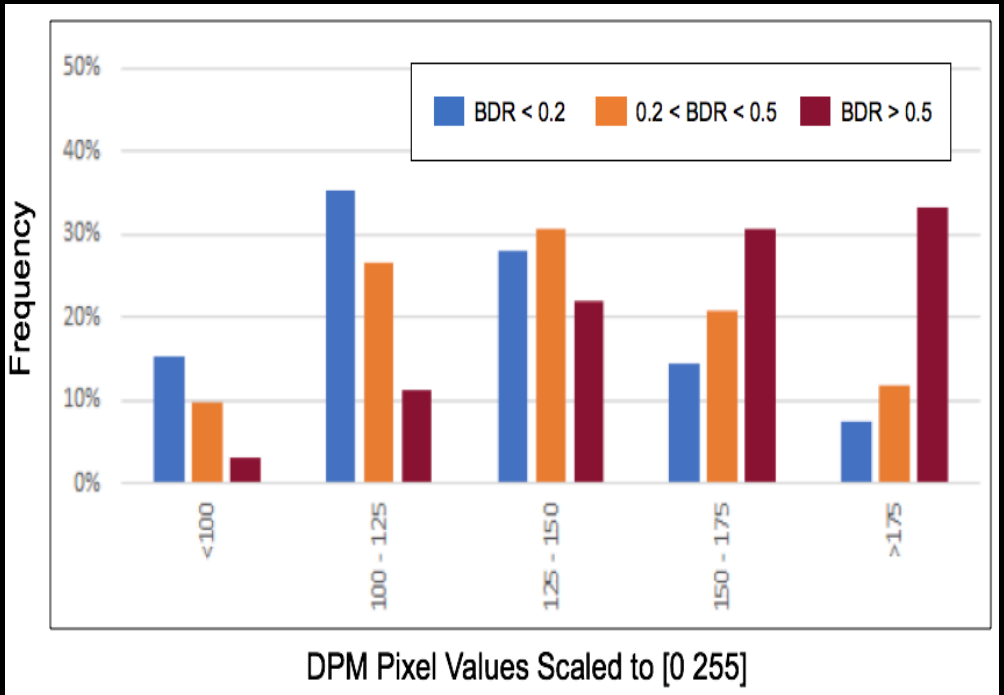
Official damage map
updated based on
ground observations
(NZ Government)

Feb 2011 Christchurch Earthquake

Economic Loss

Feb 2011 Christchurch Earthquake





shyun@jpl.nasa.gov

Economic Loss

Feb 2011 Christchurch Earthquake

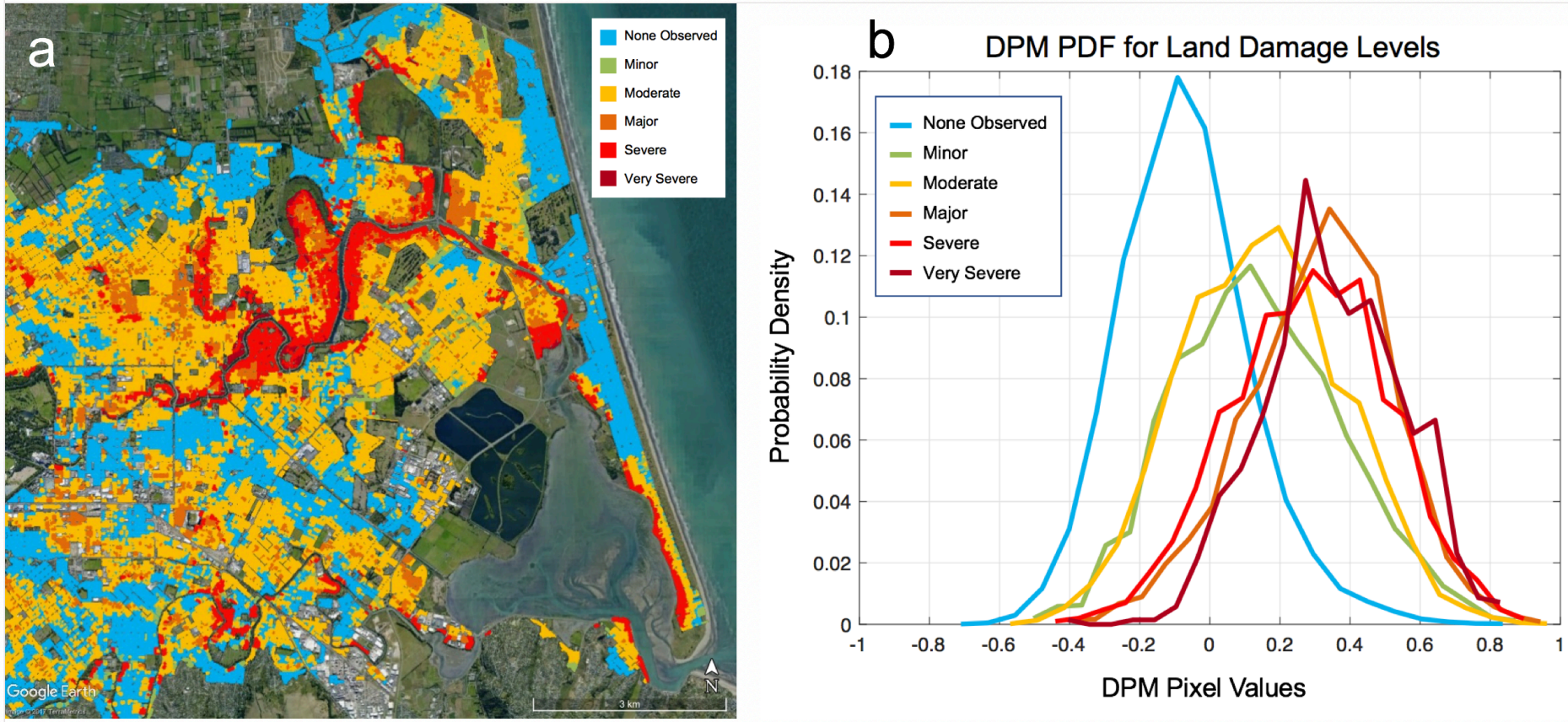


Figure 11. a) Land damage map, b) Histogram of the DPM for each level of the land damage.

shyun@jpl.nasa.gov

M7.8 April 2015 Gorkha Earthquake

The Economist | Topics | Current edition | More

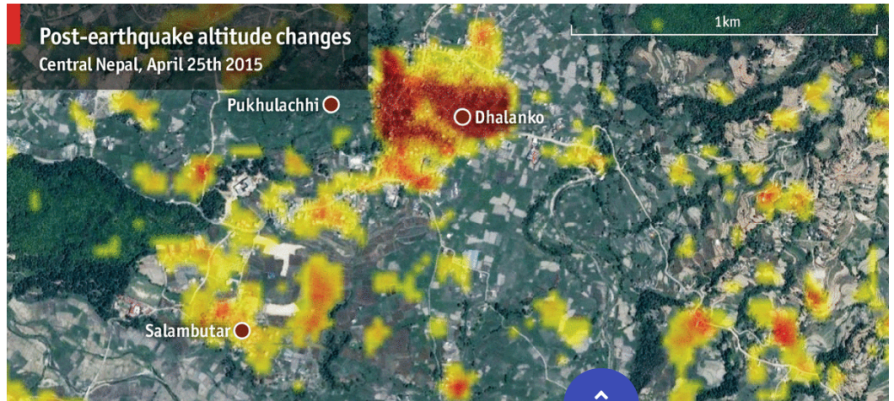
Earthquake rescue

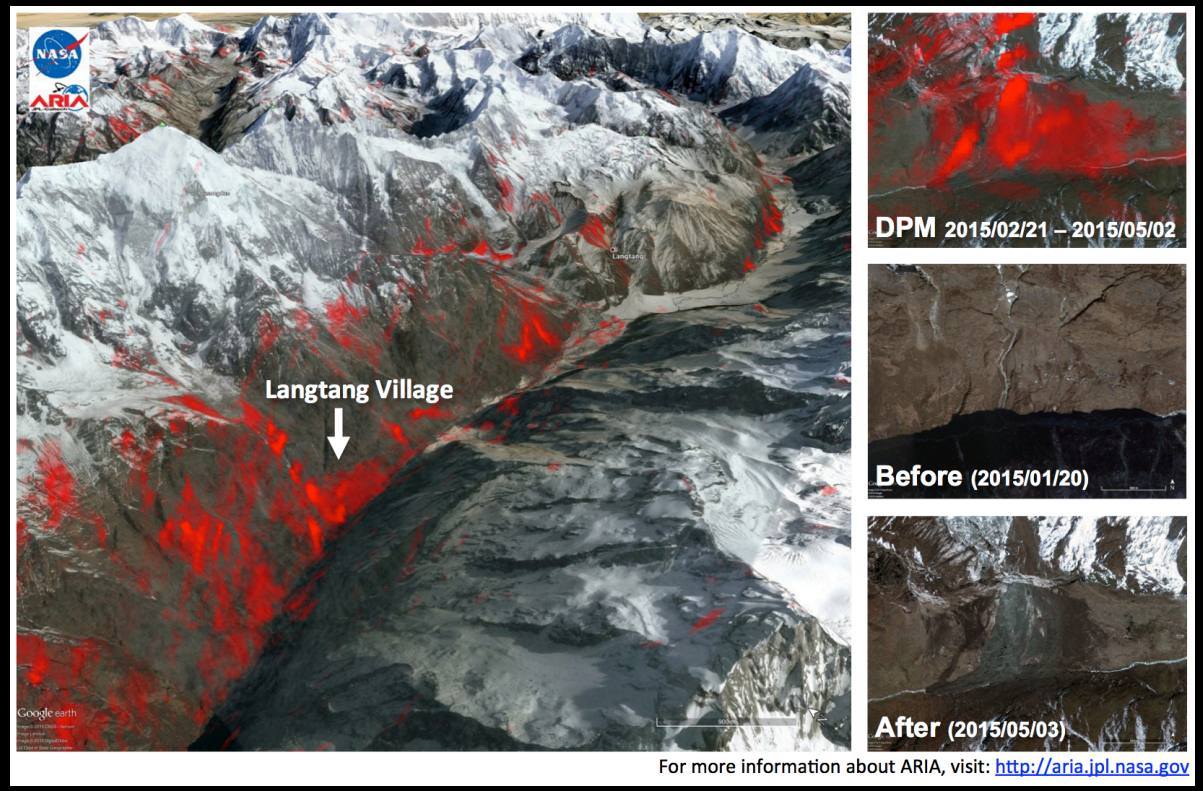
Compare and contrast

A better way to use satellite images to save lives after tremors

Print edition | Science and technology ›

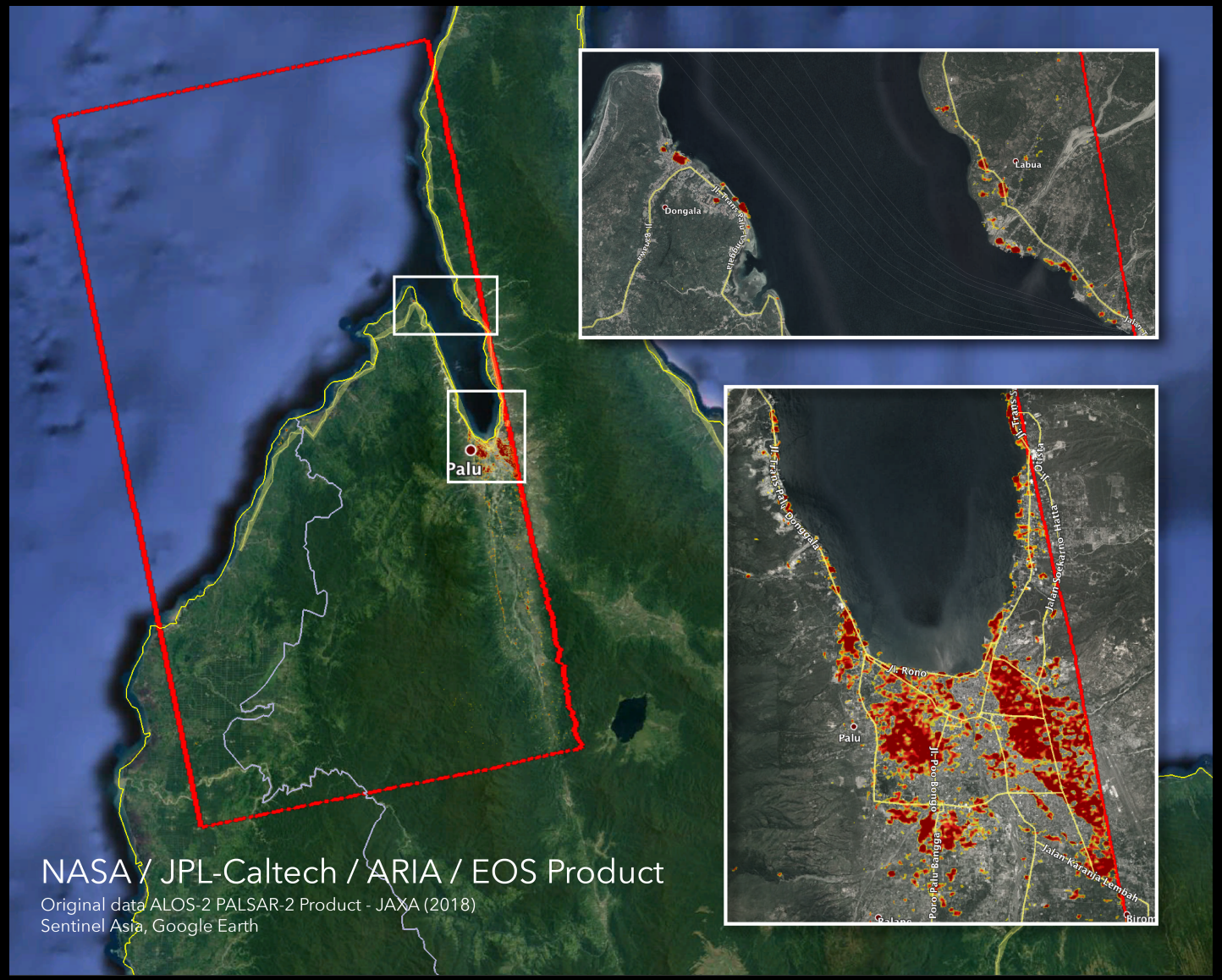
Nov 14th 2015 | Los Angeles

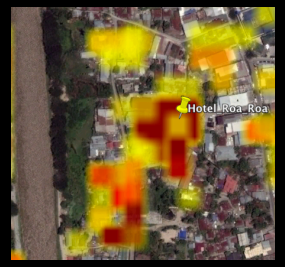


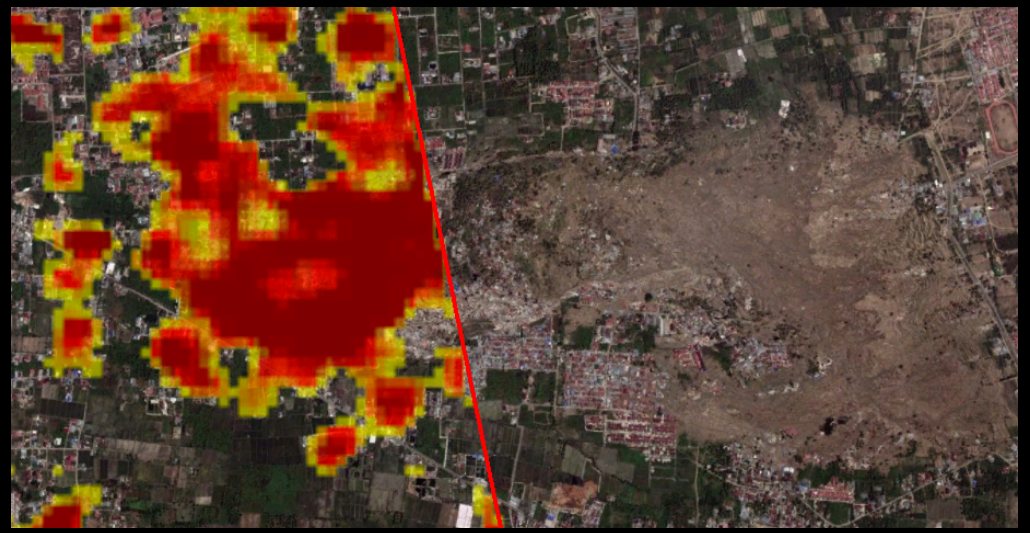


Yun et al., 2015 SRL

September 2018 M7.5 Palu Earthquake, Indonesia







How to Mitigate Earthquake-Induced Landslides

The 2018 M_w 7.5 Palu earthquake

- Landslides triggered by the earthquake caused a great deal of damage.
- These landslides were a result of irrigation practices, for rice cultivation, that activated a previously nonexistent liquefaction hazard.
- Patches of trees (or dry land) can mitigate such hazard.
- The outcome of the study has immediate impact on the decision-making process for response and resilience.

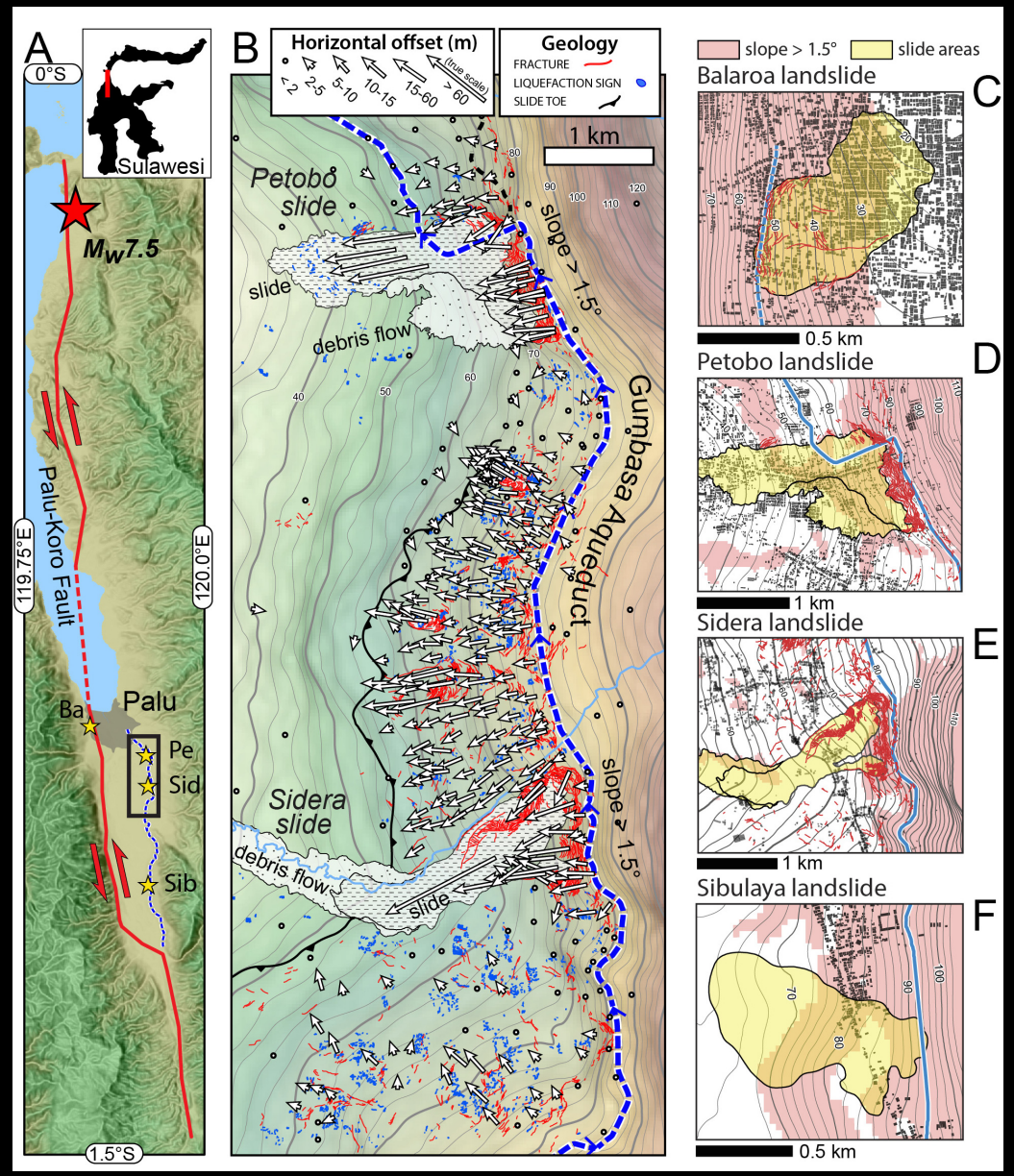
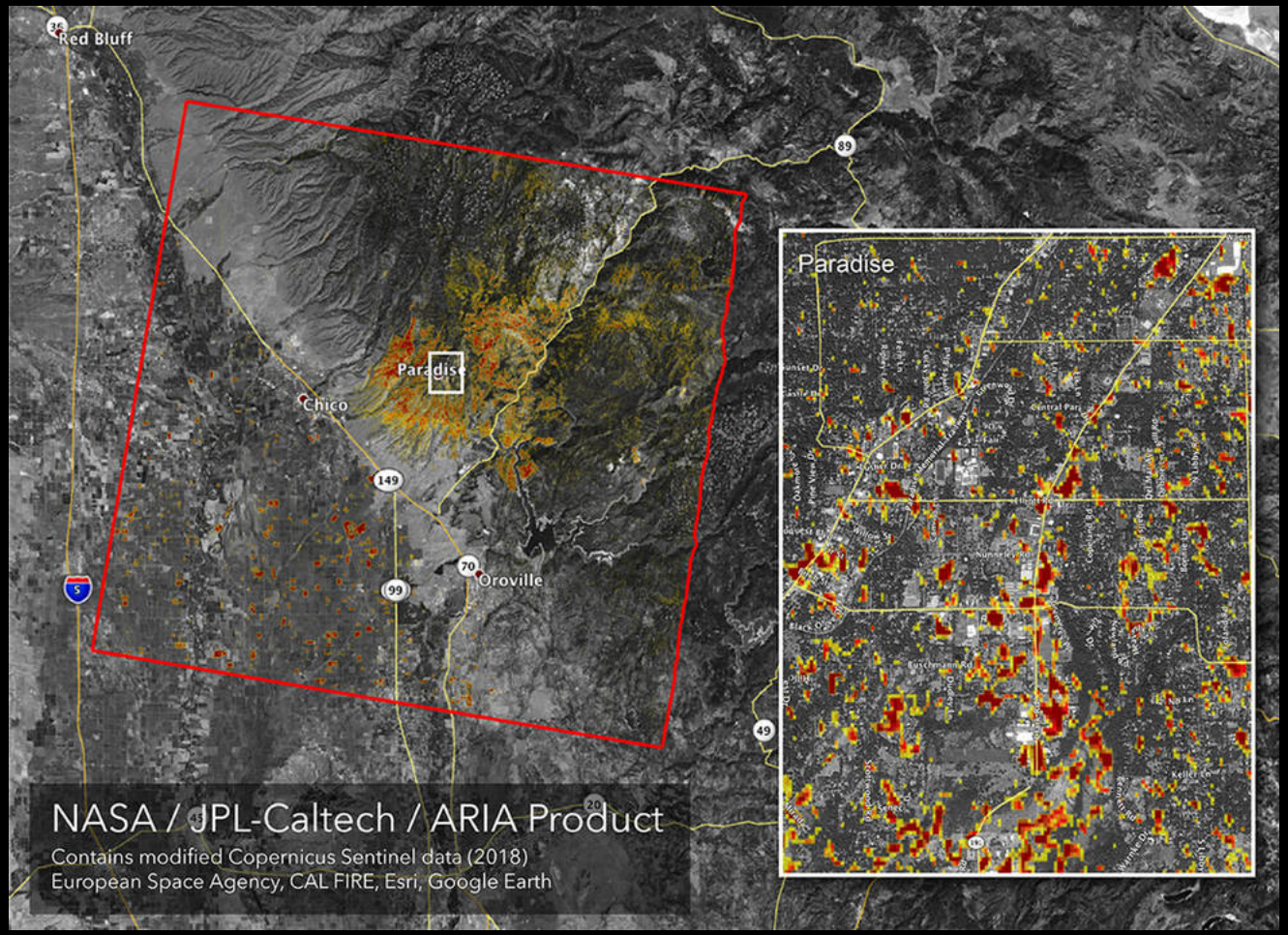


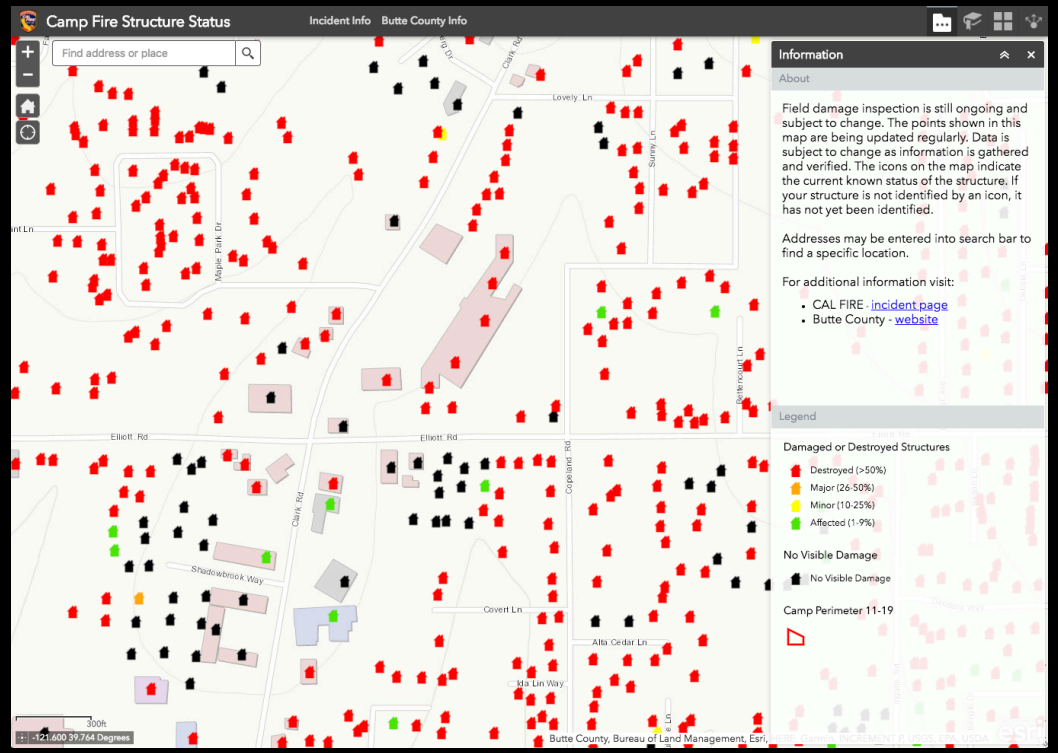
Figure by Kyle Bradley; Data from Planet.
Bradley et al., in review with Nature Geoscience, 2019

Camp Fire, Northern California (November 2018)

ARIA DPM from Sentinel-1



CAL FIRE Data: Camp Fire Structure Status



- No time stamp info available
- Screen captures used (by Maricar Rabonza)
- Provided lower bound of the current status

https://www.nasa.gov/feature/jpl/updated-nasa-damage-map-of-camp-fire-from-space
https://calfire-forestry.maps.arcgis.com/apps/webappviewer/index.html?id=5306cc8cf38c4252830a38d467d33728&extent=-13547810.5486%2C4824920.1673%2C-13518764.4778%2C4841526.1117%2C102100

CAL FIRE Structure Status: Camp Fire, Northern California (November 2018)

Affected (1-9%)

Minor (10-25%)

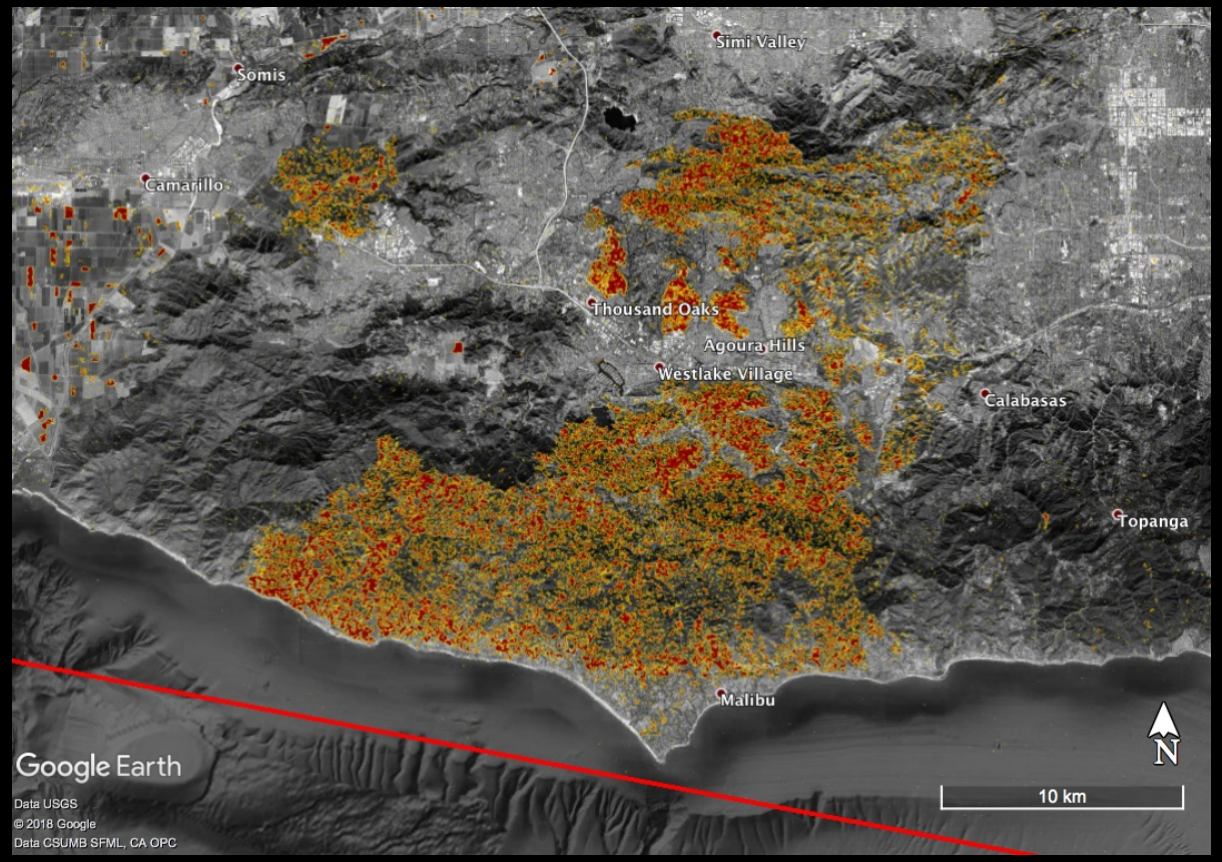
Major (26-50%)

Destroyed (>50%)

Destroyed (>50%)

Woolsey Fire, Southern California (November 2018)

ARIA DPM from Sentinel-1



2018-11-11 6:00 AM

False Color Image (Planet)

2018-11-11 10:30 AM

https://www.nasa.gov/feature/jpl/nasas-aria-maps-california-wildfires-from-space

"We estimated that Louisiana would have about 27,000 damaged homes, but it was through the acquisition of SAR data and other remotely sensed data that we were able to see that it was a much larger impact than we had forecast."

Glenn Russell, FEMA
After the August 2016 Louisiana Floods

"It is so fascinating to see this map. The pattern of the distribution of red areas correlate with most realities on the ground."

Indra Sharan, OFDA, USAID
From Nepal after the M7.8 2015 Gorkha Earthquake

"During our reconnaissance missions we have used damage proxy maps (DPMs)…. My findings clearly show that the DPM published right after the event was very effective in defining collapsed buildings."

Paolo Zimmaro, UCLA/GEER
After GEER fieldwork of the 2016 Central Italy earthquakes

"After the tragic August earthquake in Amatrice, Italy, NASA's JPL produced maps of the greatest damage. These sophisticated maps will be used in the rebuilding efforts."

Barack Obama, Former President of the US
At the White House with Mateo Renzi on Oct 28, 2016

ARIA Global Response & Science

ARIA DPM/FPM on MEDIA ALOS-2, 49 items

September 2018 M7.5 Sulawesi Earthquake, Indonesia

"NASA's ARIA Maps Indonesia Quake, Tsunami Damage", ***JPL News (was on the JPL front page)***, October 5, 2018. Available online at: https://www.jpl.nasa.gov/news/news.php?feature=7253

"NASA's ARIA Maps Indonesia Quake, Tsunami Damage", ***JPL Photojournal***, October 5, 2018. Available online at: https://photojournal.jpl.nasa.gov/catalog/PIA22746 ***JPL Space Images*** at: https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA22746

"Sulawesi Island, Indonesia Earthquake and Tsunami 2018", ***NASA Applied Sciences Disasters Program Website***, September 28, 2018. Available online at: https://disasters.nasa.gov/sulawesi-island-indonesia-earthquake-and-tsunami-2018

September 2018 M6.6 Hokkaido Earthquake, Japan

"Japan Earthquakes (ARIA Damage Proxy Map)", ***JPL Photojournal***, September 10, 2018. Available online at: https://photojournal.jpl.nasa.gov/catalog/PIA22696 ***JPL Space Images*** at: https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA22696

"ARIA Damage Proxy Map of Hokkaido, Japan Earthquake", ***NASA Applied Sciences Disasters Program Website***, September 10, 2018. Available online at: https://disasters.nasa.gov/hokkaido-japan-earthquake-2018/aria-damage-proxy-map-hokkaido-japan-earthquake

August 2018 Lombok Earthquakes, Indonesia

"ARIA Damage Proxy Map of Lombok, Indonesia Earthquakes", ***JPL Photojournal***, September 5, 2018. Available online at: https://photojournal.jpl.nasa.gov/catalog/PIA22495 ***JPL Space Images*** at: https://www.jpl.nasa.gov/spaceimages/details.php?id=PIA22495 ***NASA Applied Sciences Disasters Program Website***, August 19, 2018. Available online at: https://disasters.nasa.gov/lombok-indonesia-earthquake-2018/aria-damage-proxy-map-lombok-indonesia-earthquake

August 2017 Texas Floods (Hurricane Harvey), TX, USA

"New NASA Satellite Flood Map of Southeastern Texas (Sentinel-1 Data)", ***JPL Photojournal***, August 31, 2017. Available online at: https://photojournal.jpl.nasa.gov/catalog/pia21932 ***JPL Space Images*** at: https://www.jpl.nasa.gov/spaceimages/details.php?id=pia21932

"Updated NASA Satellite Flood Map of Southeastern Texas (ALOS-2 Data)", ***JPL Photojournal***, August 31, 2017. Available online at: https://photojournal.jpl.nasa.gov/catalog/pia21931 ***JPL Space Images*** at: https://www.jpl.nasa.gov/spaceimages/details.php?id=pia21931

"Extent of Texas Flooding Shown in New NASA Map", ***JPL Photojournal***, August 30, 2017. Available online at: https://photojournal.jpl.nasa.gov/catalog/pia21928 ***JPL Space Images*** at: https://www.jpl.nasa.gov/spaceimages/details.php?id=pia21928

August 2016 Louisiana Flood, LA, USA

"Sizing Up Floods from Space: NASA Science for U.S. Flood Response", ***NASA Applied Sciences Video***, December 9, 2016. Available online at: http://appliedsciences.nasa.gov/programs/disasters-program https://youtu.be/wqLghXCMxBI

August 2016 M6.2 Amatrice Earthquake, Italy

"NASA-Produced Maps Help Gauge Italy Earthquake Damage", ***NASA Feature Story***, October 5, 2016. Available online at: http://www.nasa.gov/feature/jpl/nasa-produced-maps-help-gauge-italy-earthquake-damage

"NASA-Produced Maps Help Gauge Italy Earthquake Damage", ***JPL News***, October 5, 2016. Available online at: http://www.jpl.nasa.gov/news/news.php?feature=6637

"New Satellite Damage Maps Assist Italy's Earthquake Disaster Response", ***JPL Photojournal***, September 1, 2016. Available online at: http://photojournal.jpl.nasa.gov/catalog/pia20897

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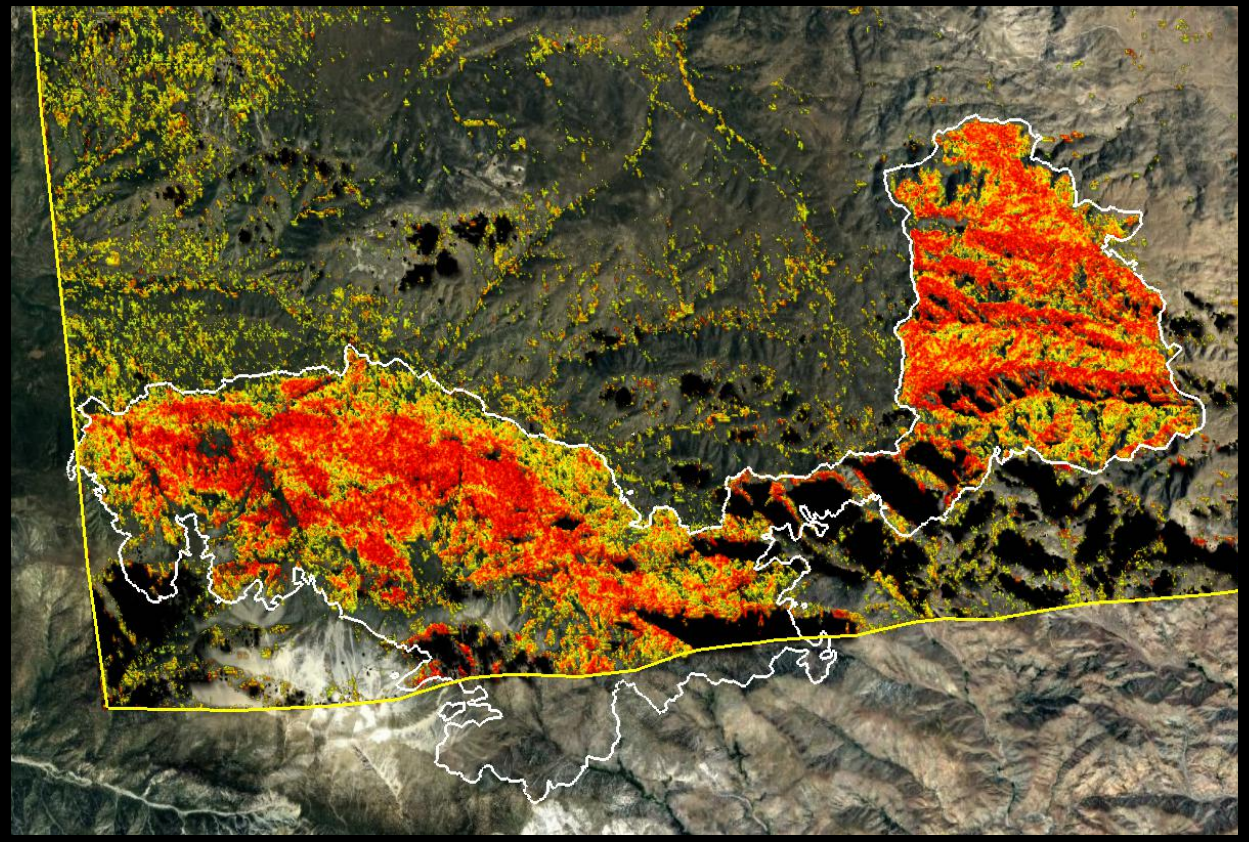
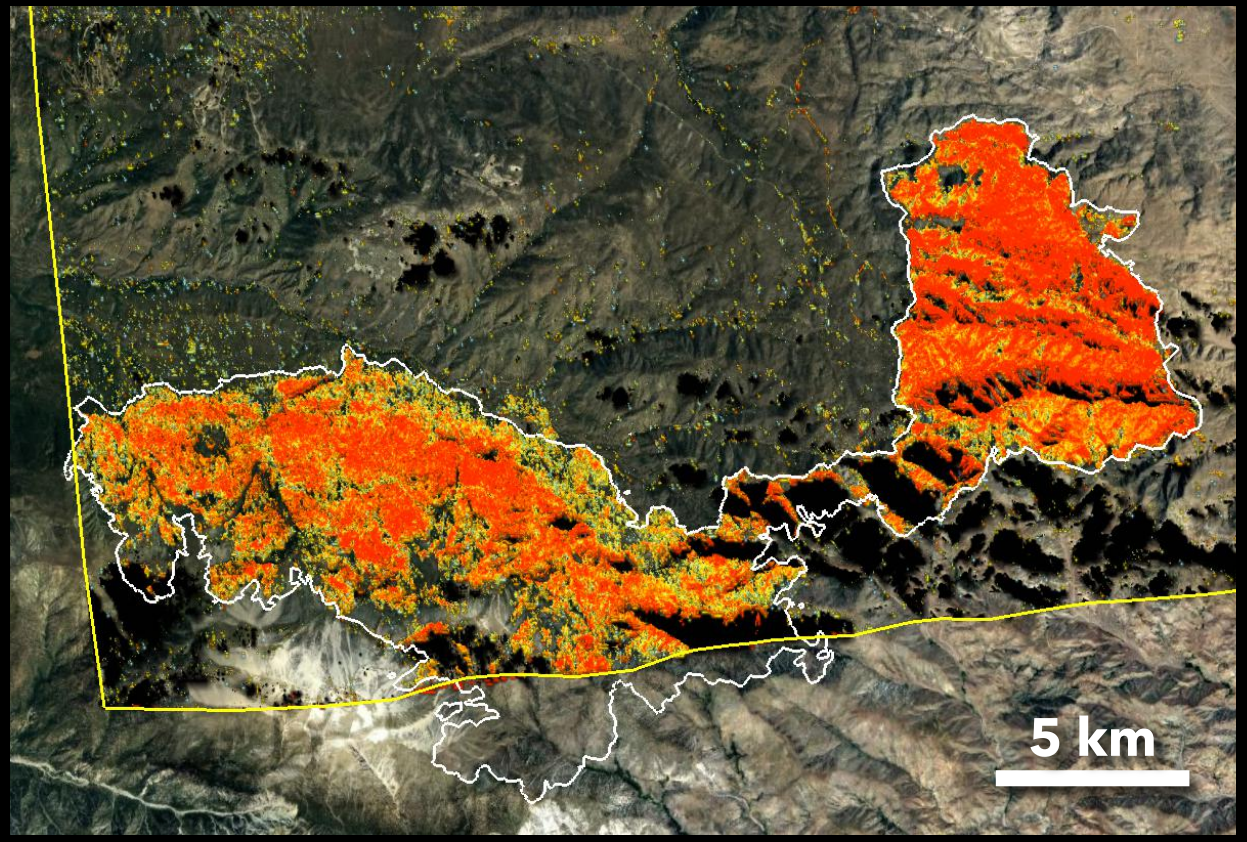
Multi-temporal Multi-polarization Interferometric Coherence Analysis July 2015 Lake Fire, California (UAVSAR)

DPM1



DPM2



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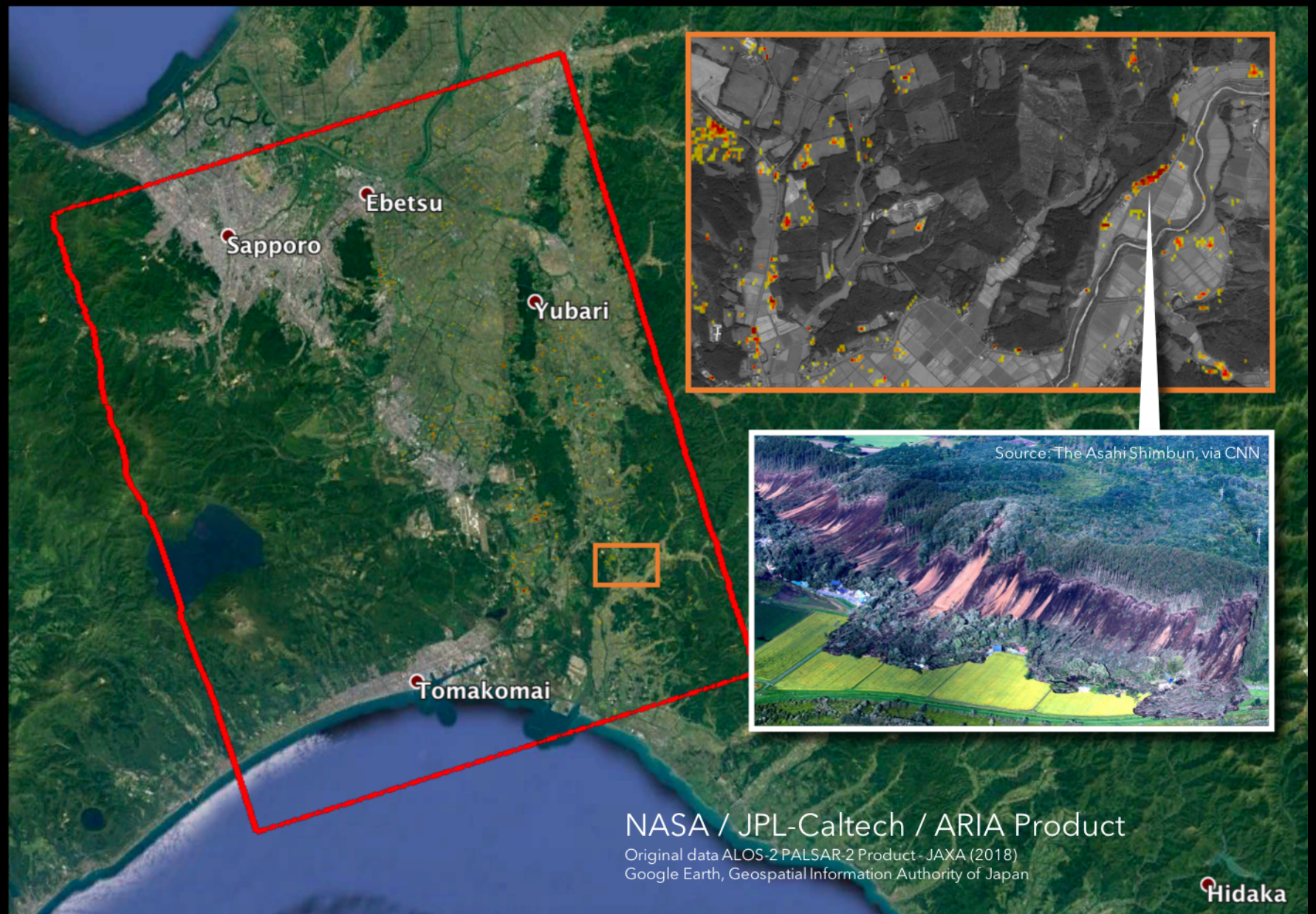
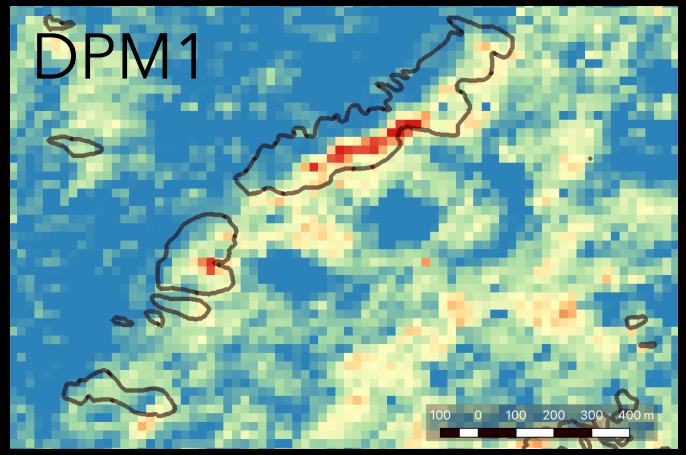
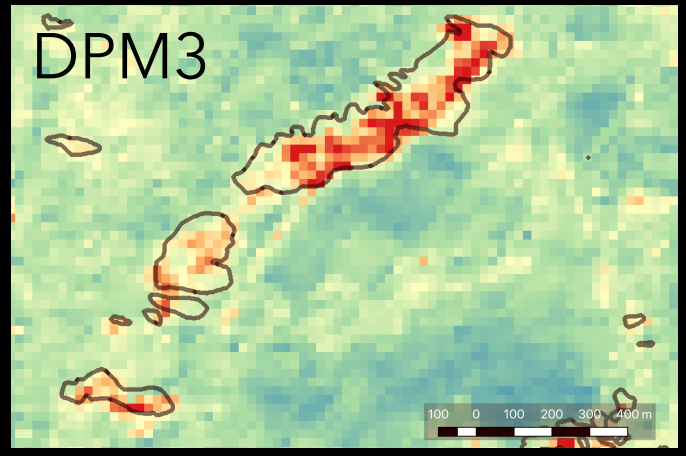
Landslides Triggered by the M6.6 Hokkaido Earthquake (Sept 2018)



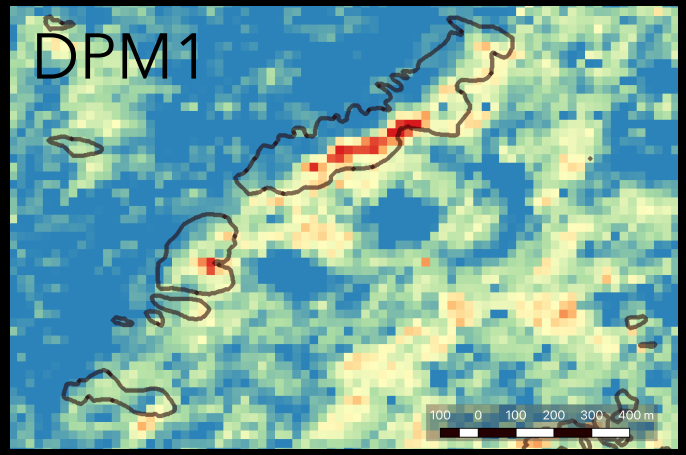
Landslides Triggered by the M6.6 Hokkaido Earthquake (Sept 2018)

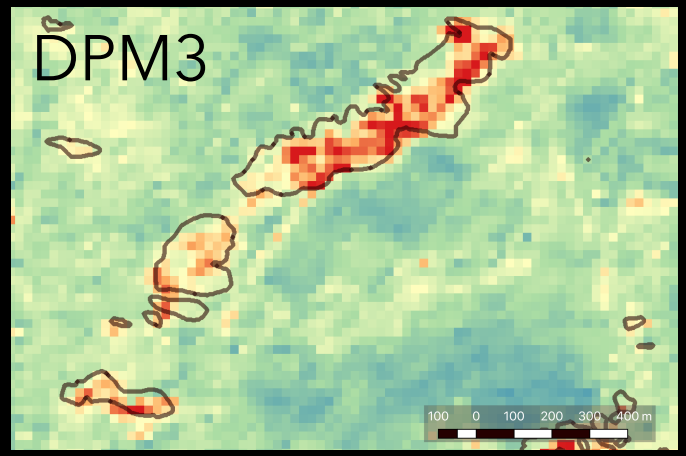




Aerial Photos by GSI

Landslides Triggered by the M6.6 Hokkaido Earthquake (Sept 2018)





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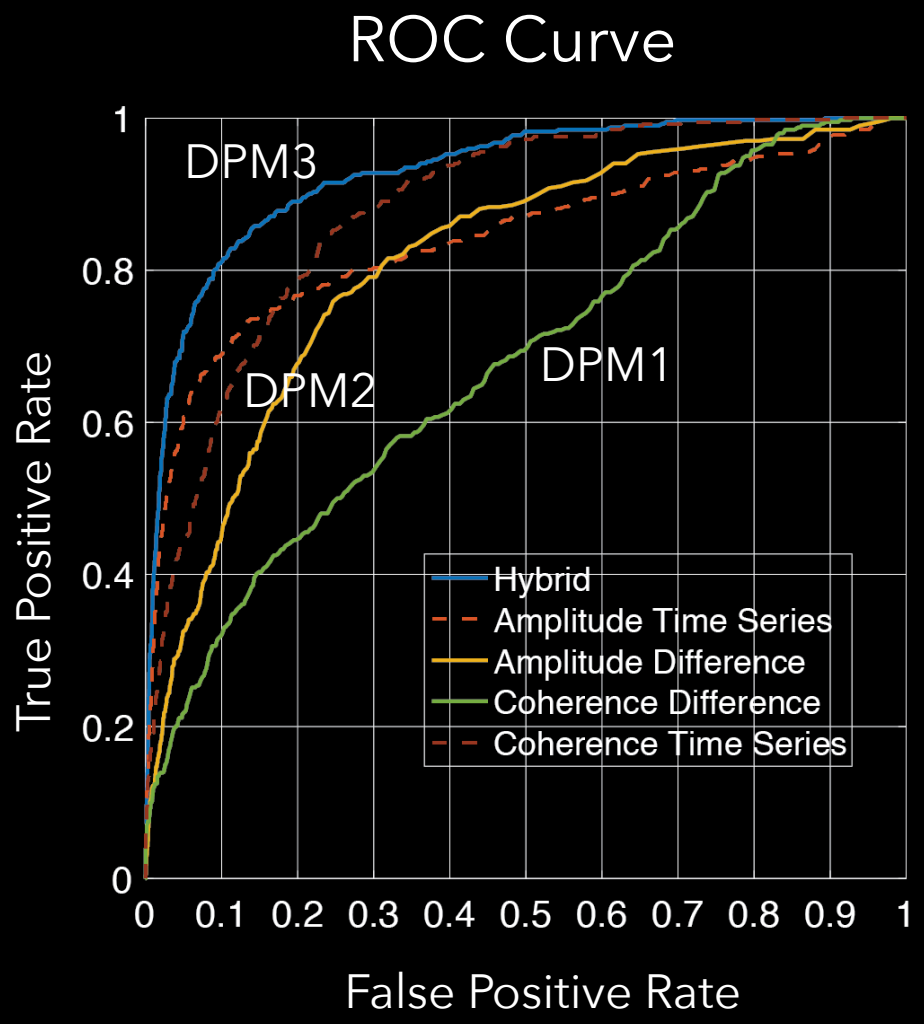

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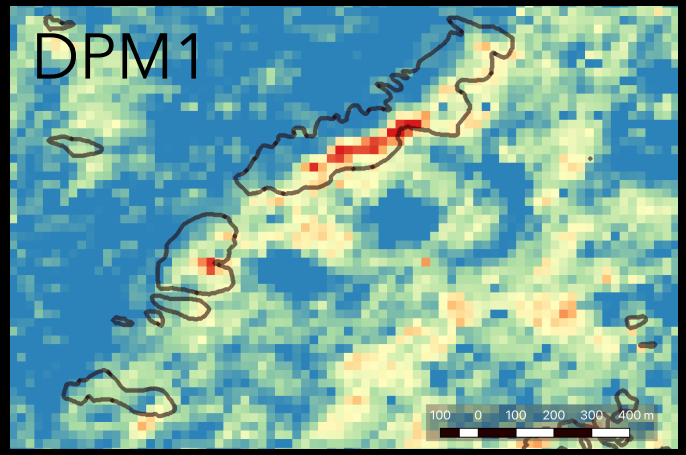

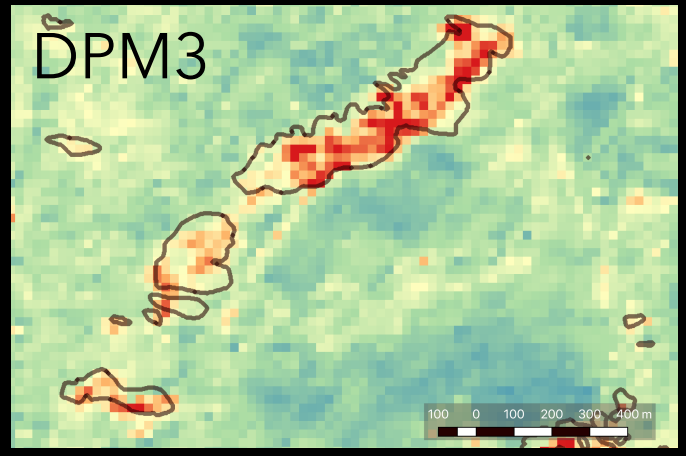

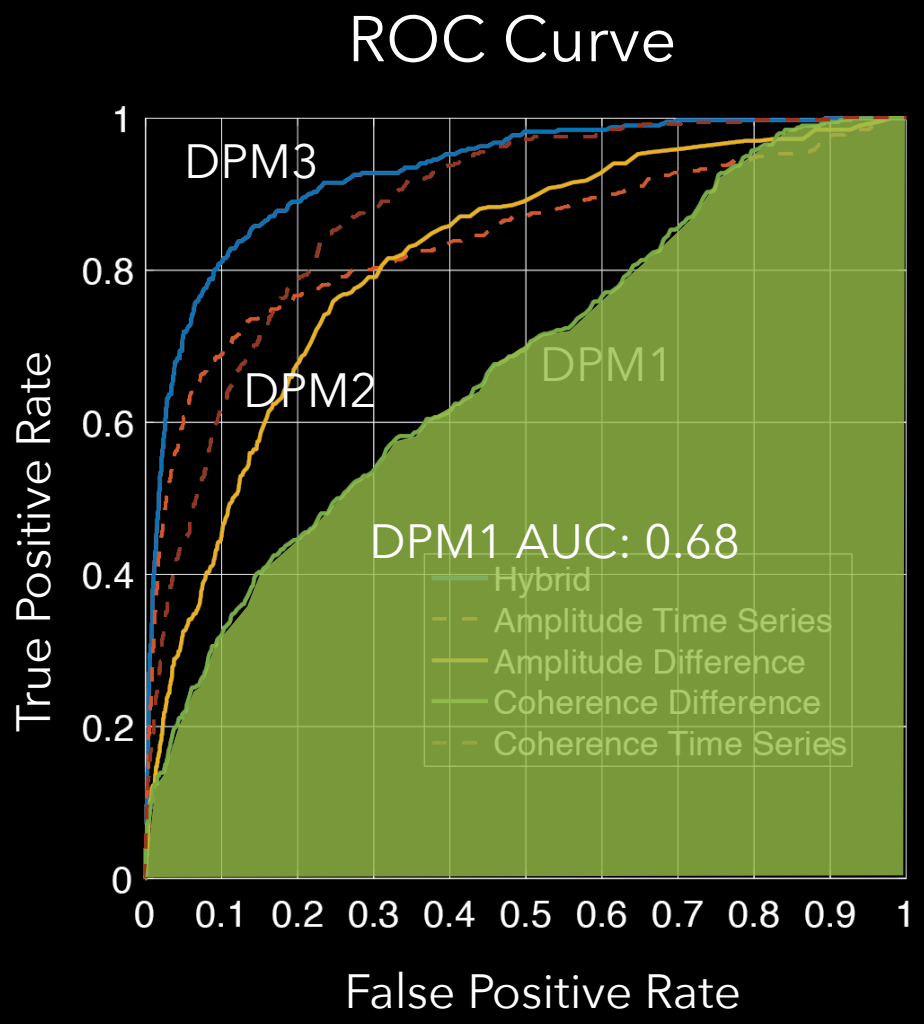

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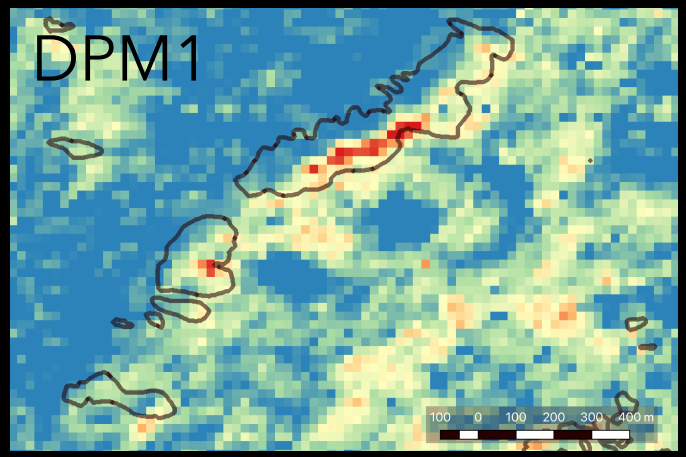
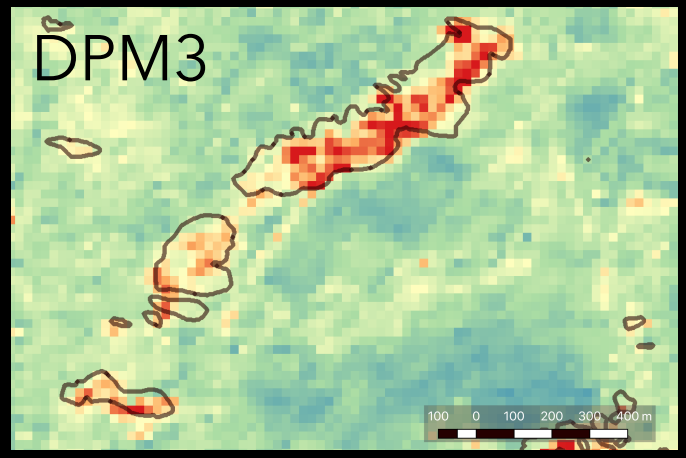
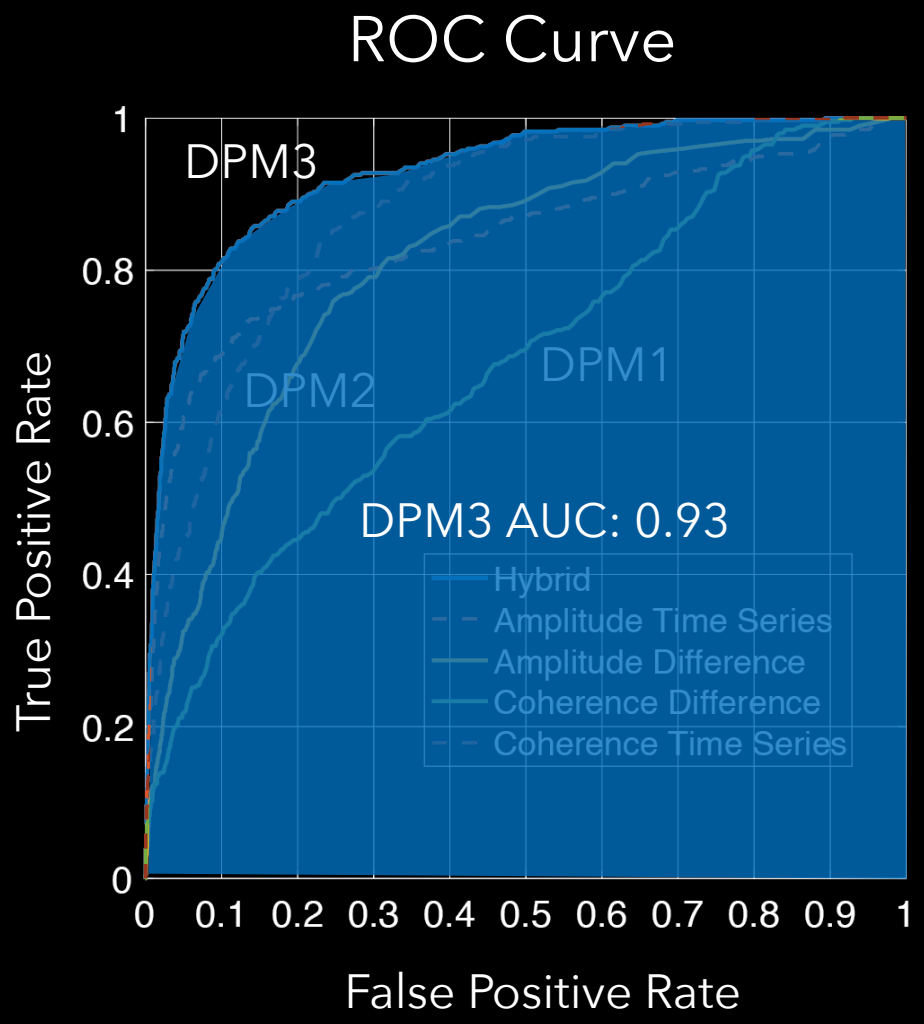


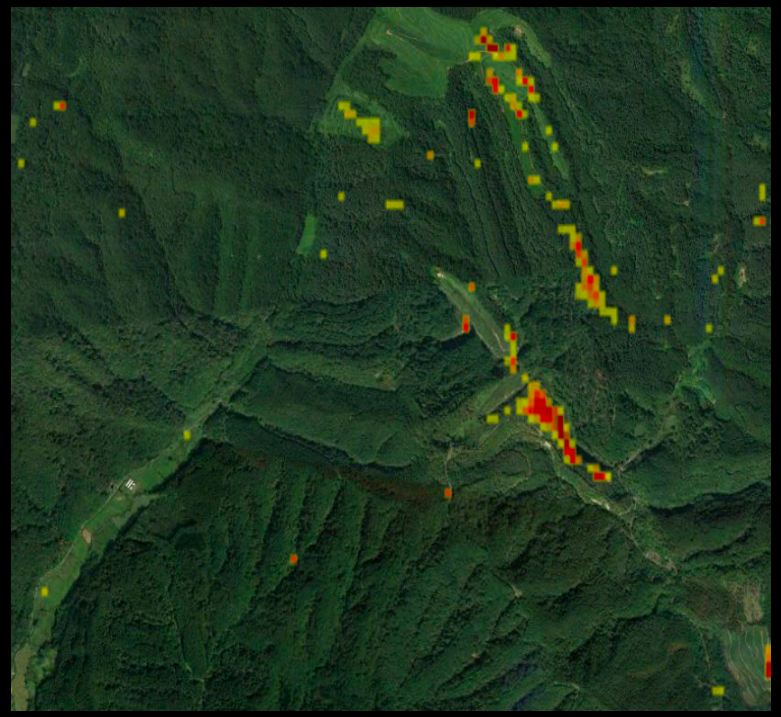




Landslides Triggered by the M6.6 Hokkaido Earthquake (Sept 2018)

Aerial Photos by GSI

DPM1



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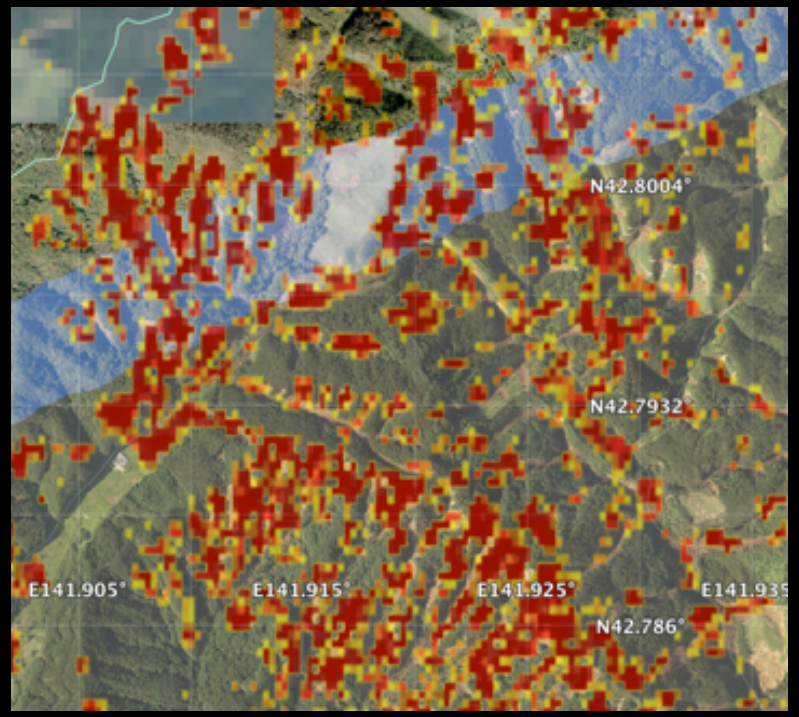
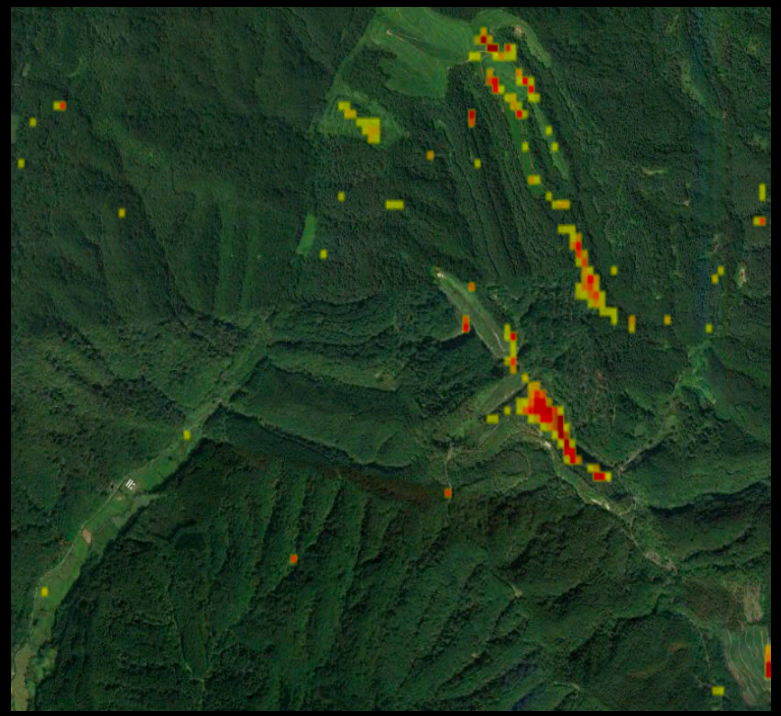


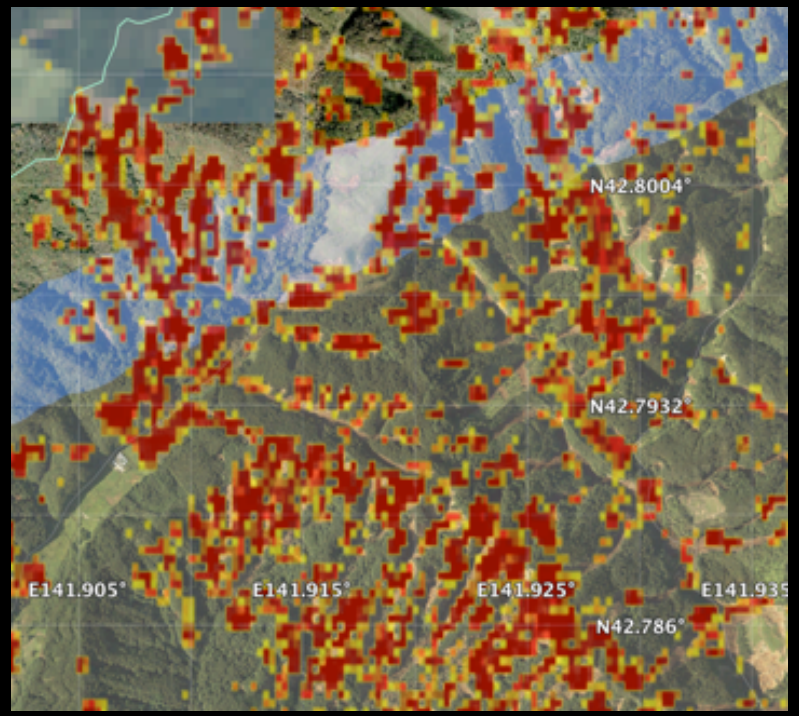
SAR Processing Latency

DPM1



Processing: 1 hour

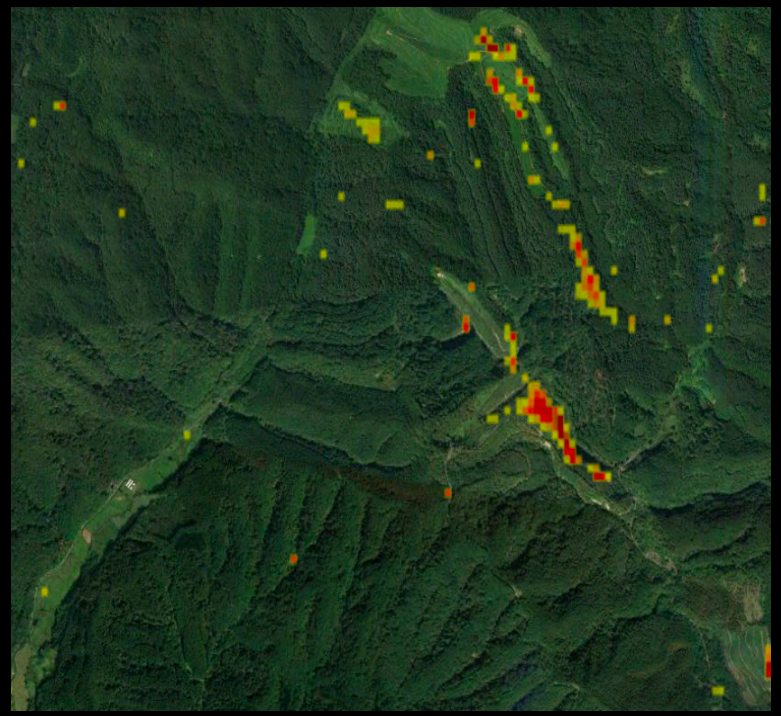
DPM2/3



Processing: 26 days

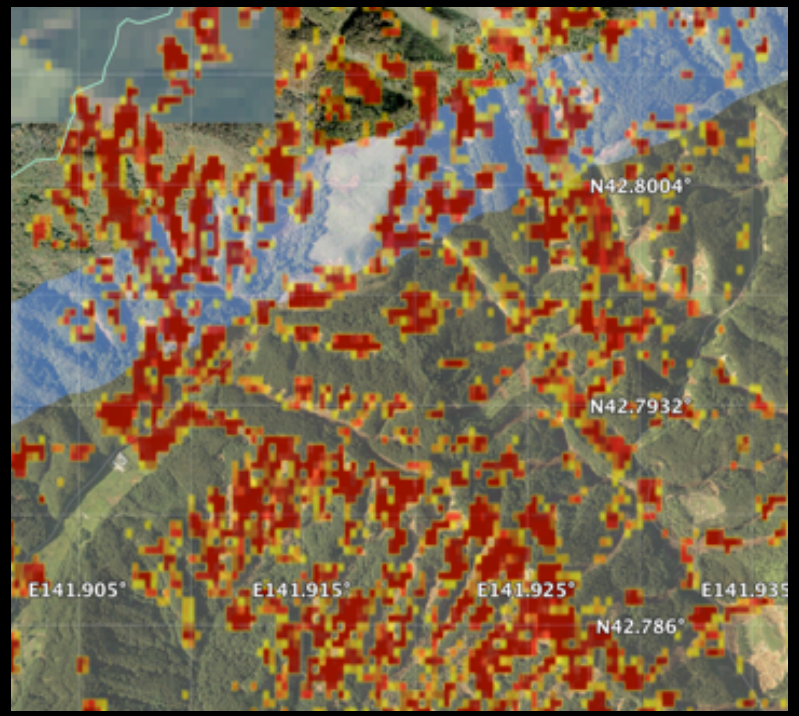
SAR Processing Latency

DPM1



Processing: 1 hour

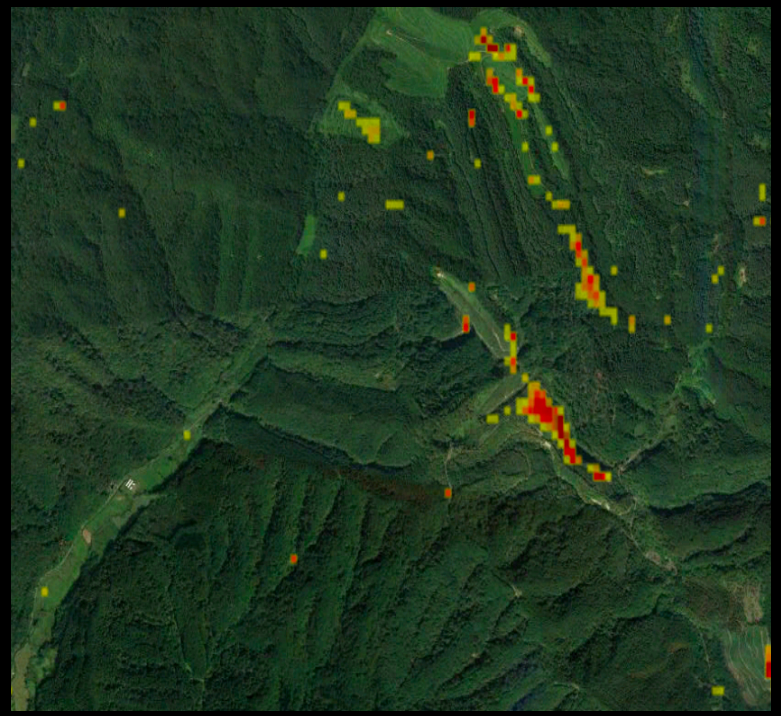
DPM2/3



Processing: 26 days → 1 hour

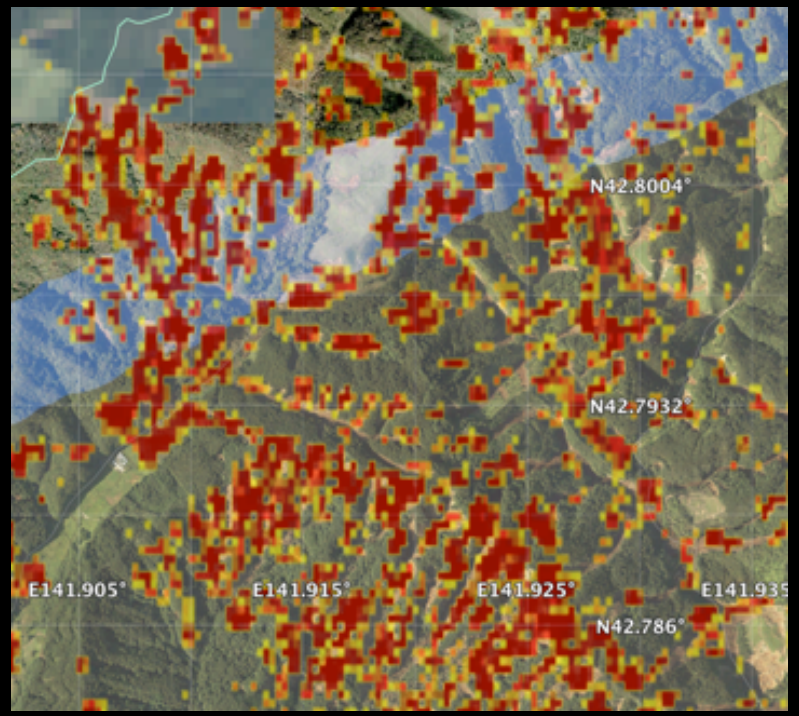
SAR Download Latency

DPM1



Processing: 1 hour
Downloading: 1.5 hours

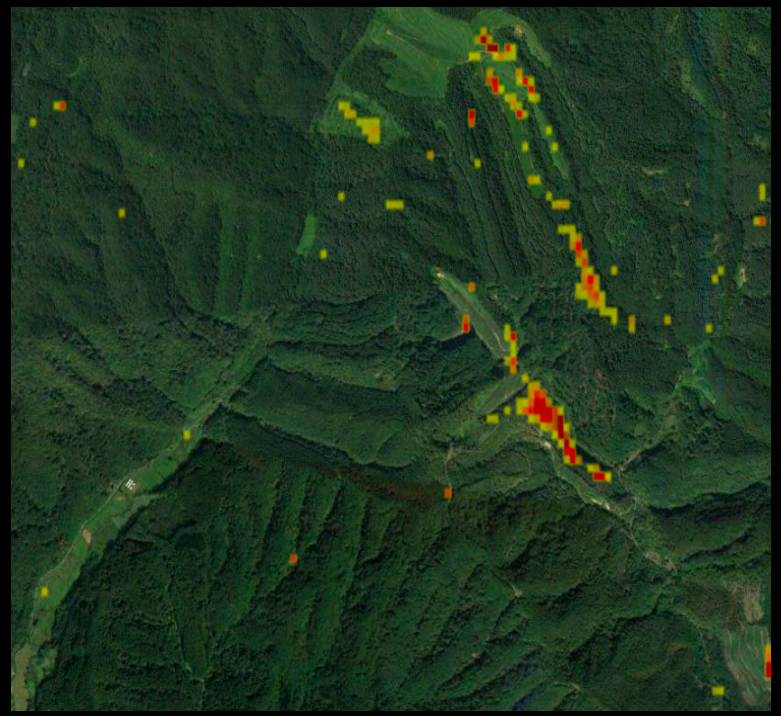
DPM2/3



Processing: 26 days → 1 hour
Downloading: 40 hours

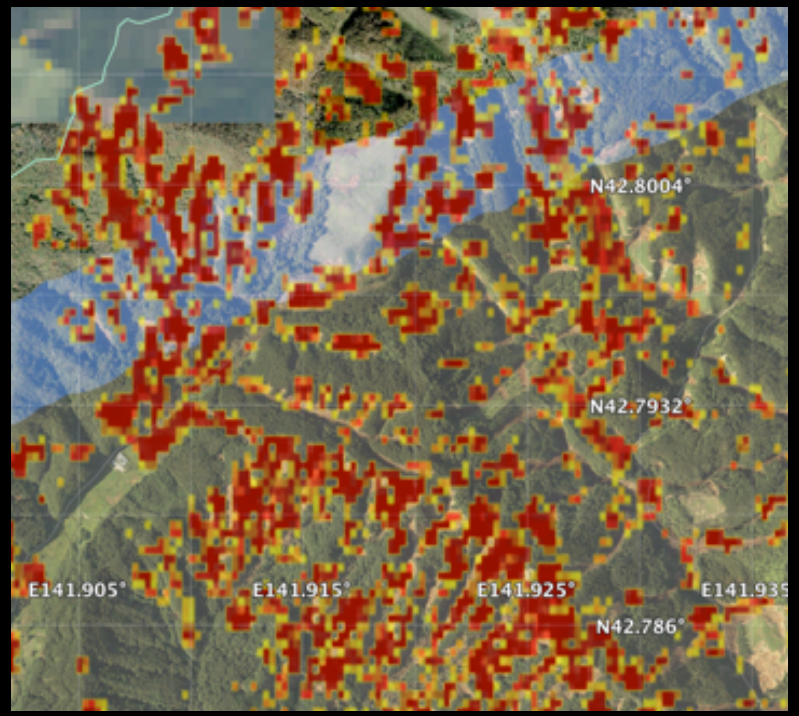
SAR Download Latency

DPM1



Processing: 1 hour
Downloading: 1.5 hours

DPM2/3



Processing: 26 days → 1 hour
Downloading: 40 hours → 0.5 hours

EOS proposal to Amazon
NASA-JAXA agreement

NASA
ARIA
JPL-Caltech
JPL
amazon web services
ARIA
EARTH OBSERVATORY OF SINGAPORE
amazon web services
ARIA-SG
GEO
GROUP ON EARTH OBSERVATIONS

Can we “translate” what RADAR sees rapidly and accurately enough to help efficient response and effective resilience?

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