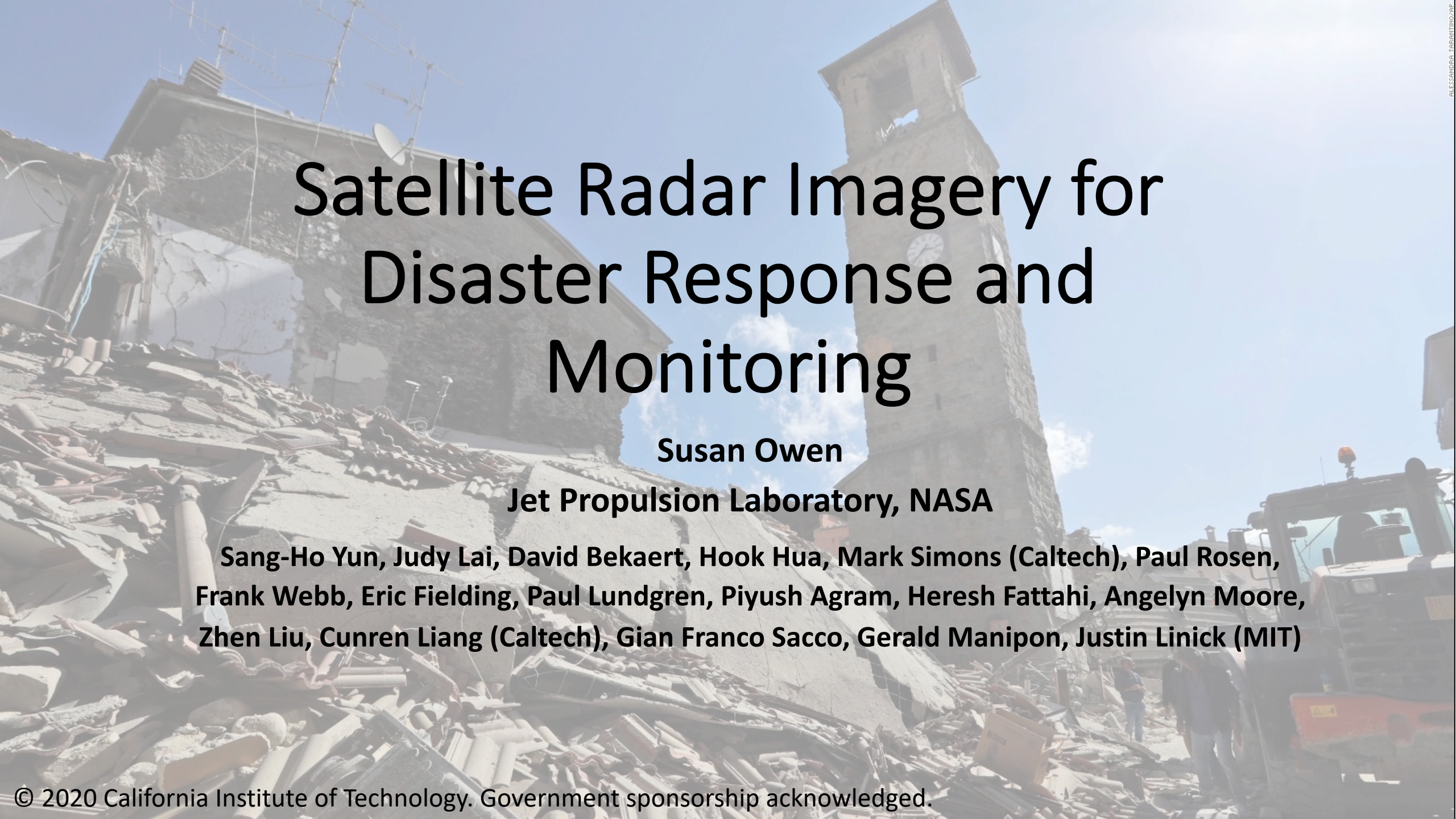


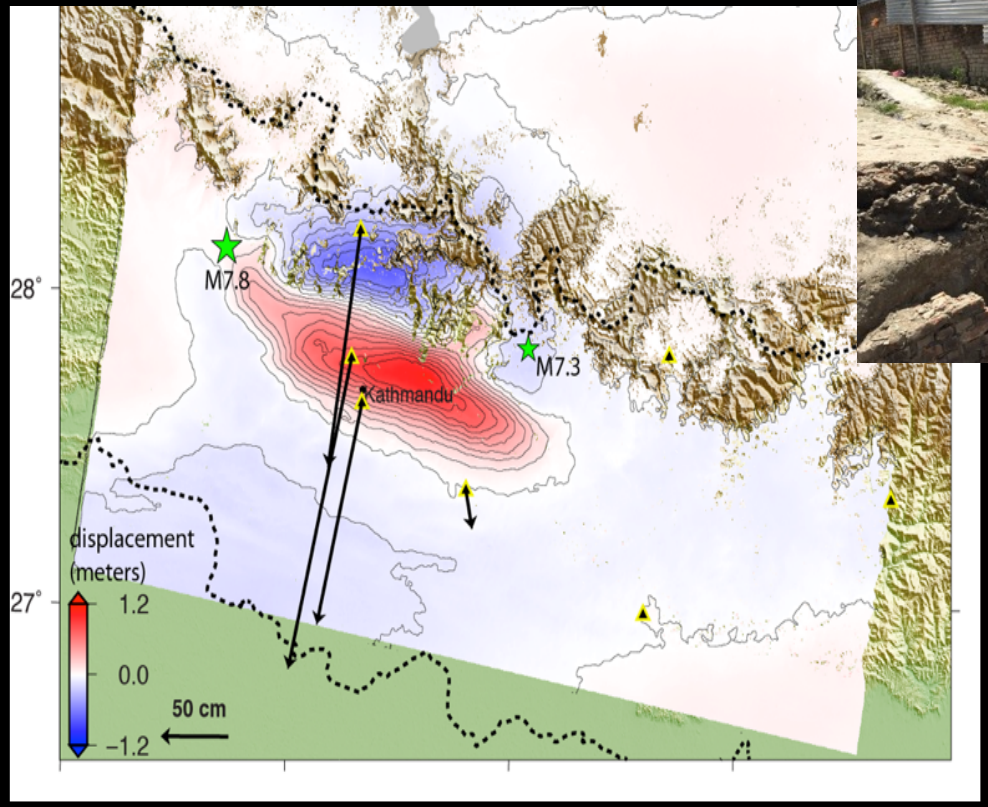
Satellite Radar Imagery for Disaster Response and Monitoring

Susan Owen

Jet Propulsion Laboratory, NASA

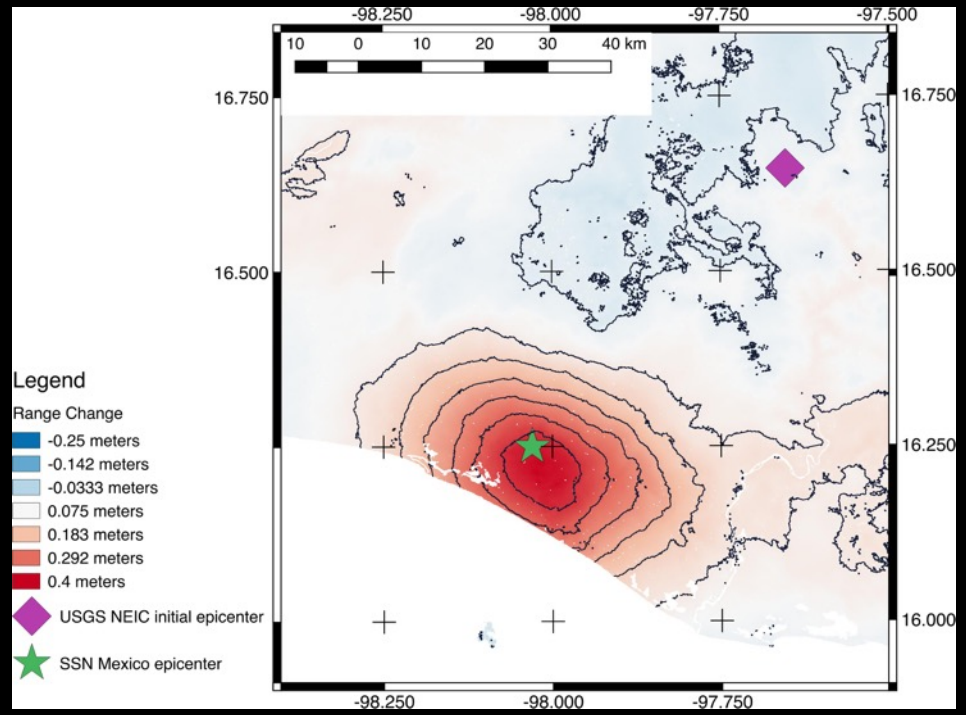
Sang-Ho Yun, Judy Lai, David Bekaert, Hook Hua, Mark Simons (Caltech), Paul Rosen, Frank Webb, Eric Fielding, Paul Lundgren, Piyush Agram, Heresh Fattahi, Angelyn Moore, Zhen Liu, Cunren Liang (Caltech), Gian Franco Sacco, Gerald Manipon, Justin Linick (MIT)

Earthquake Surface Deformation from InSAR



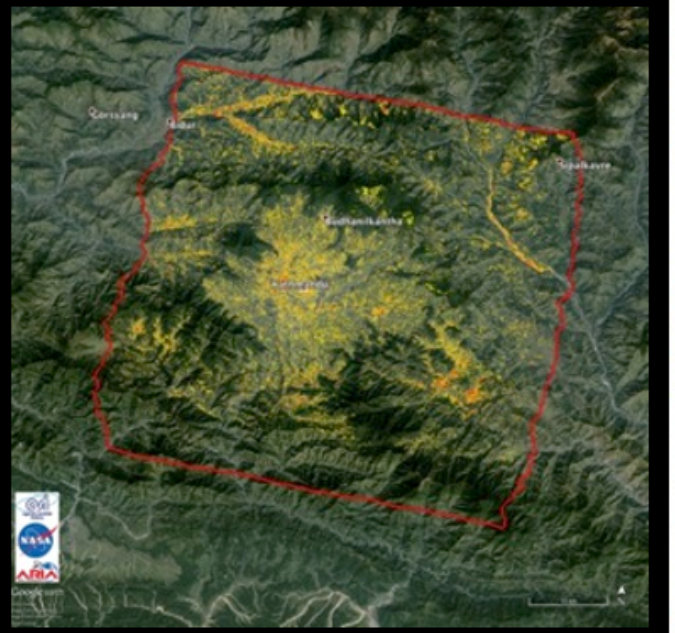
Fault rupture did not reach the surface -- has loaded shallow region of fault.

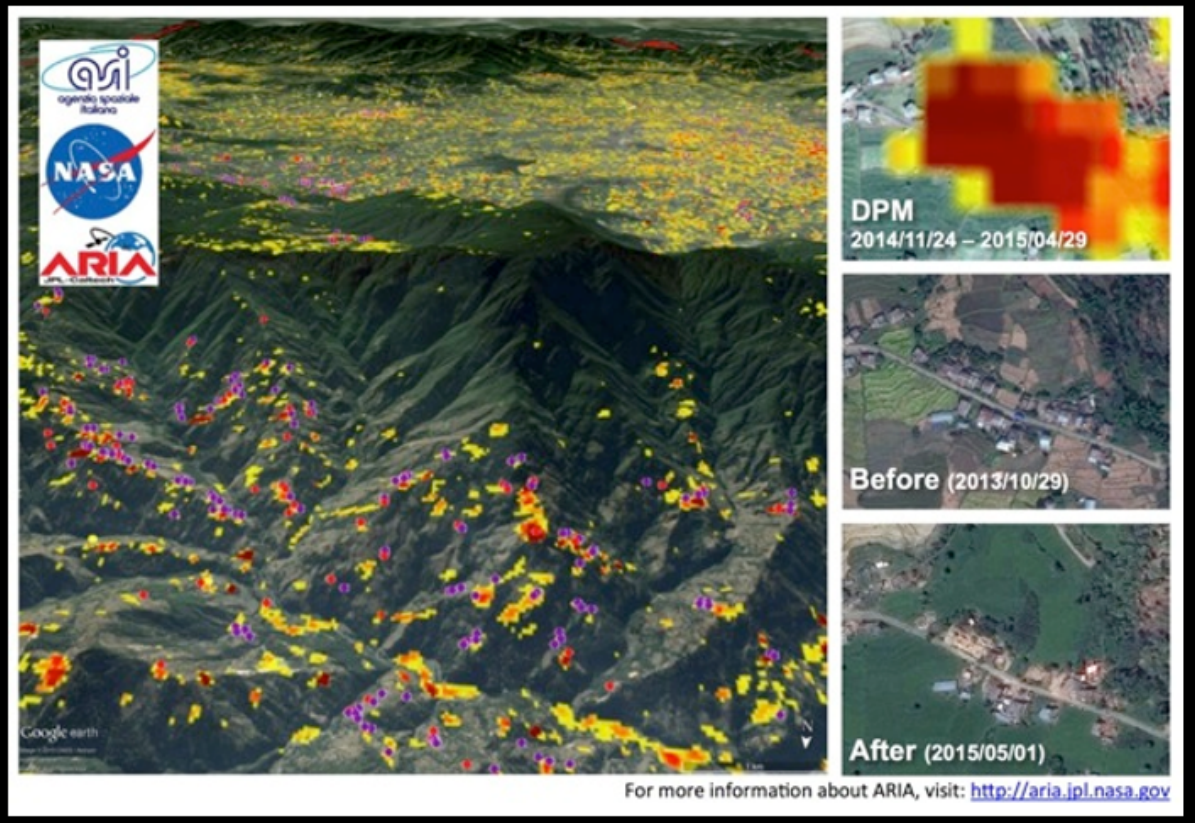
2015 M7.8 Gorkha earthquake in Nepal



2018 M7.2 Pinotepa earthquake in Oaxaca, Mexico

Damage Assessment from Radar





- Highlighted areas of potential damage by SAR data from ASI Cosmmo-SkyMed data
- Delivered to US and International agencies for their damage assessment efforts in support of humanitarian response

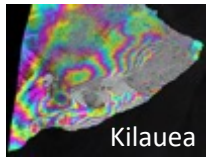
Advanced Rapid Imaging and Analysis (ARIA) project

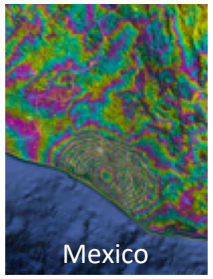
Jet Propulsion Laboratory
California Institute of Technology

- Radar Sensors
- GPS Networks
- Seismic Networks
- Optical Sensors

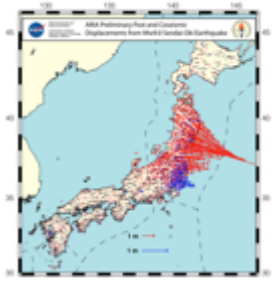
Automated Data Collection & Processing

Radar

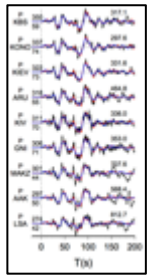




GPS



Seismology

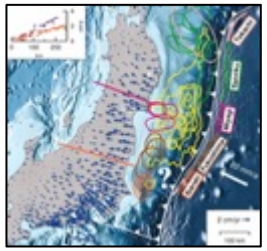


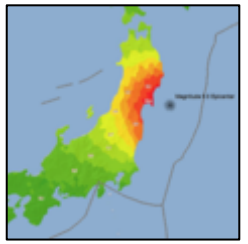
Monitoring & Near Real-Time Assessment

Partners & Collaborators

Building Damage & Flood proxy

High-Resolution Hazard Assessment from Fault Models





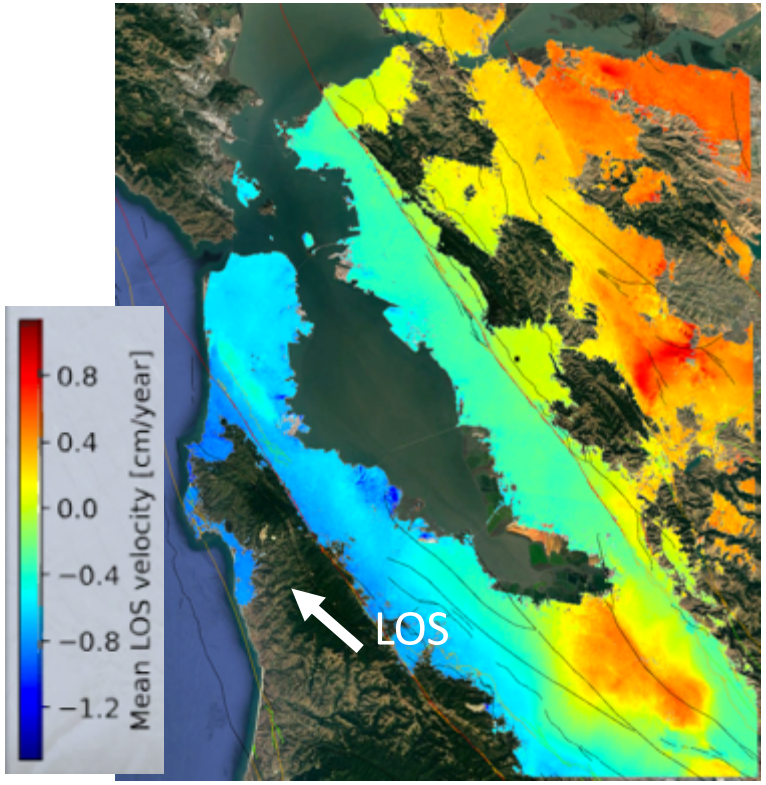
Permanent Ground Deformation

ARIA JPL-Caltech

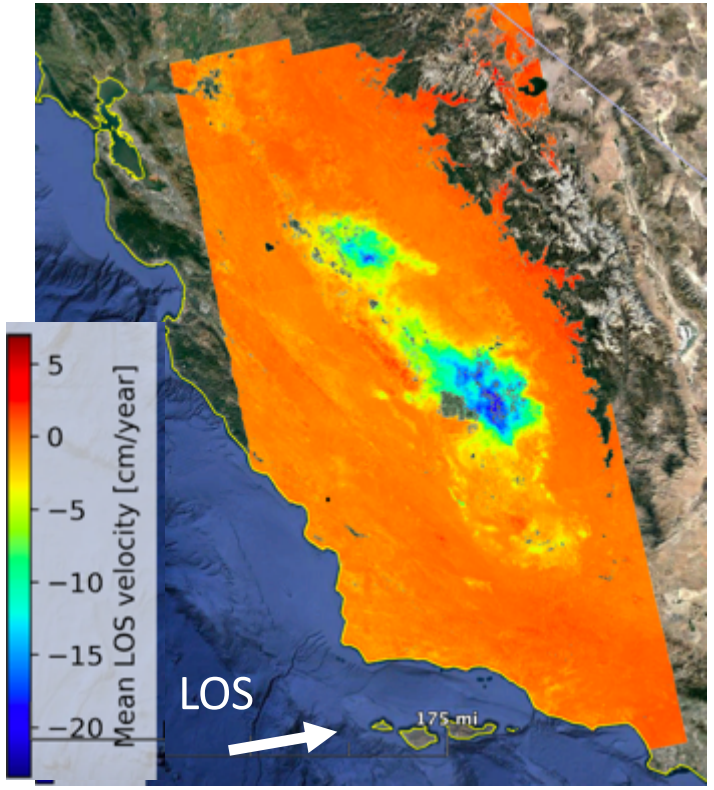
USGS science for a changing world · DHS · FEMA · SSC · The World Bank · EERI · GEM Global Earthquake Model · CAL FIRE · OES · CGS · ASI agenzia spaziale italiana · esa · ASF · DigitalGlobe · PLANET LABS · esri

Measuring Surface Deformation Useful for Monitoring

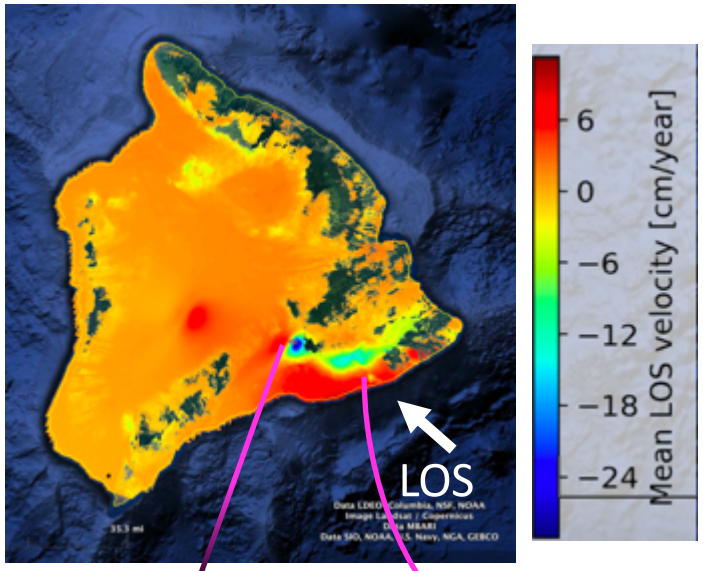
USGS interested in using ARIA to monitor faults in CA

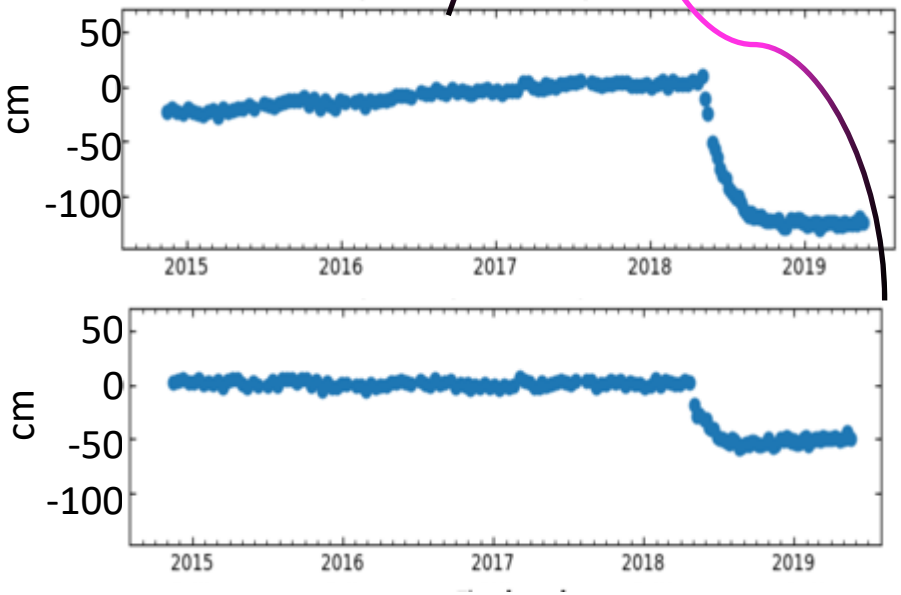


California Dept of Water Resources has been using InSAR to monitor groundwater extraction



USGS interested in using ARIA to monitor volcanos

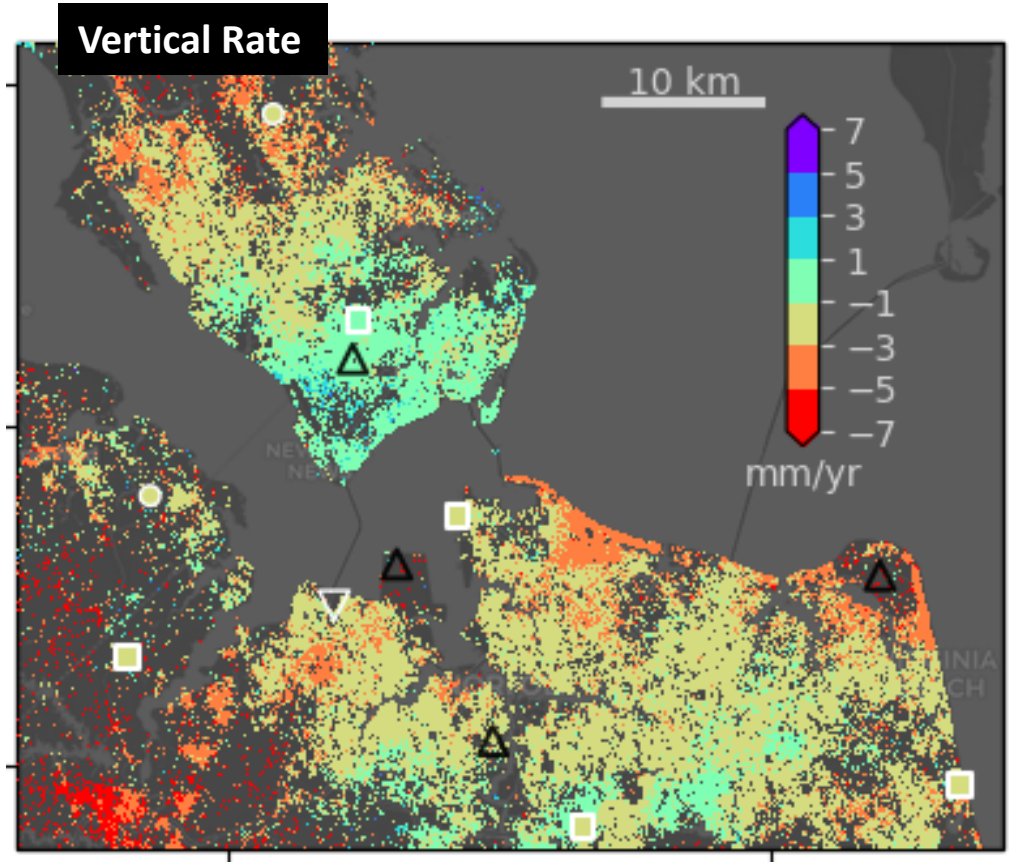


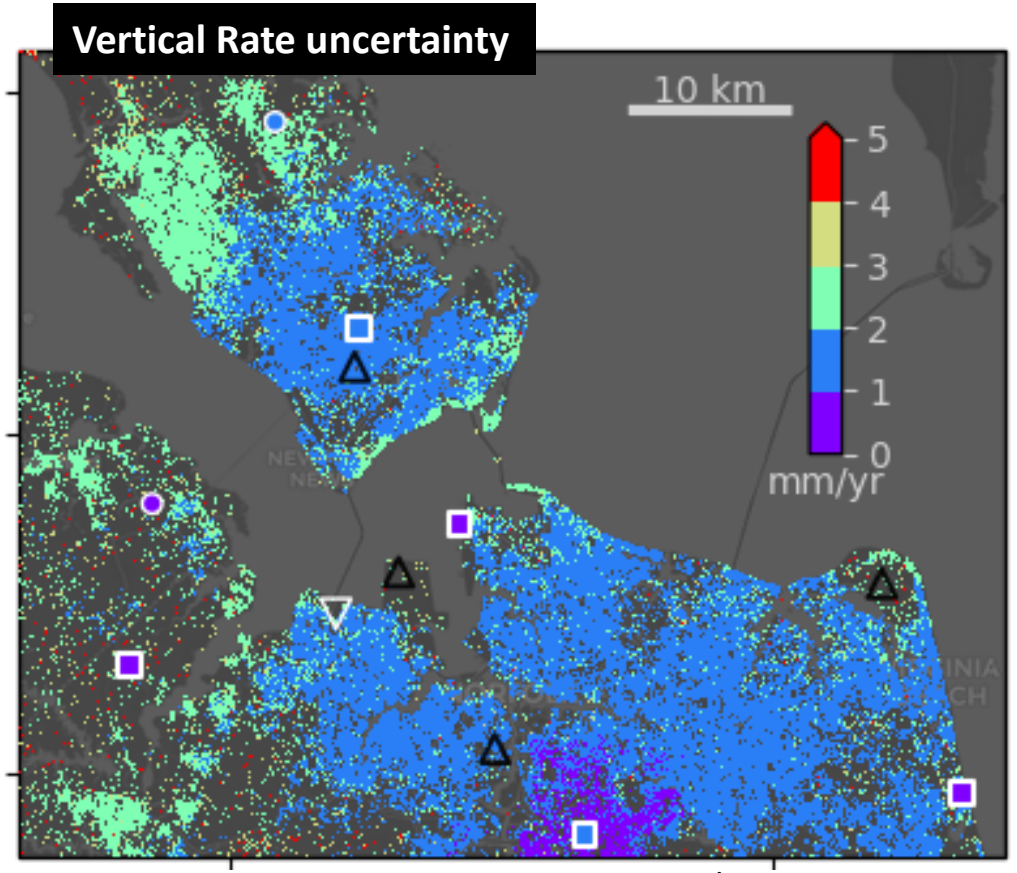


Measurements at surface used to understand where faults, water, and magma are moving underneath the surface

Using InSAR datasets for measuring coastal subsidence: Hampton Roads, Virginia

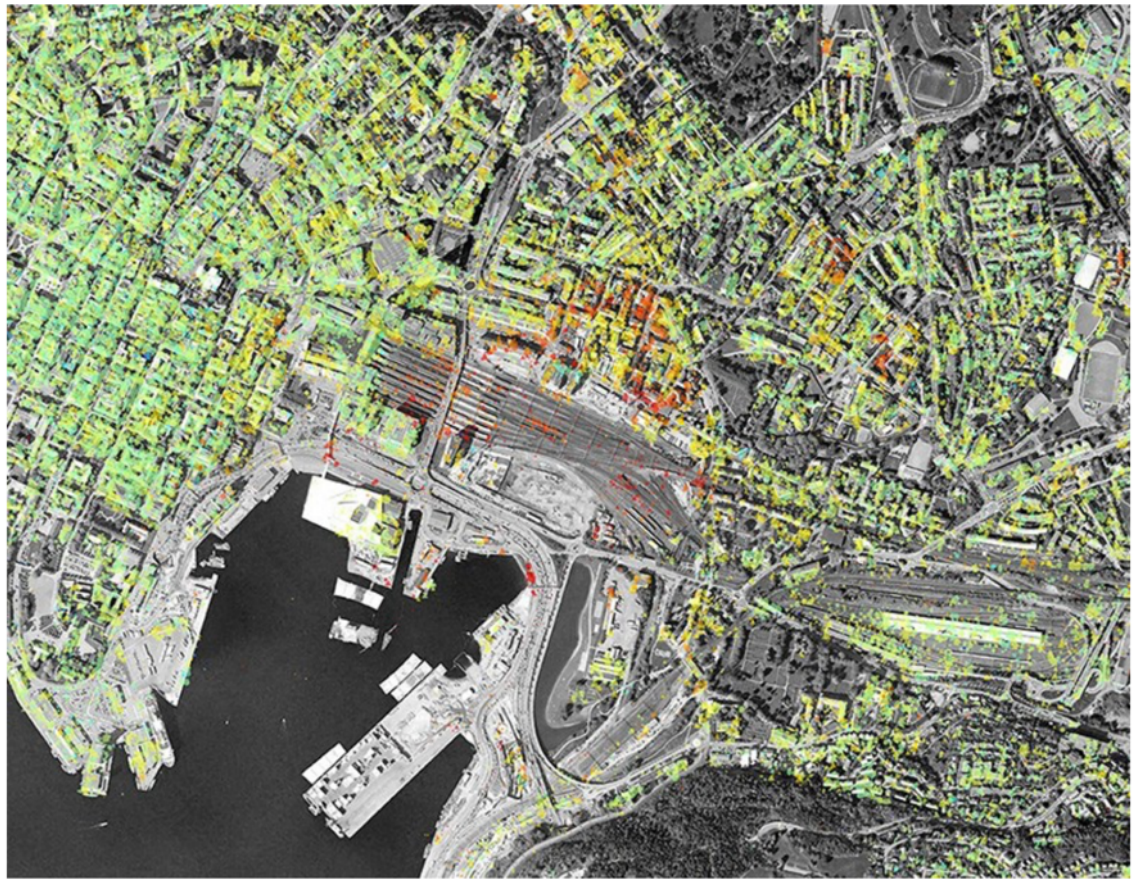
Hampton Roads





Buzzanga et al., 2020 in prep

Using InSAR for Monitoring Surface Deformation in Urban Areas: Oslo, Norway

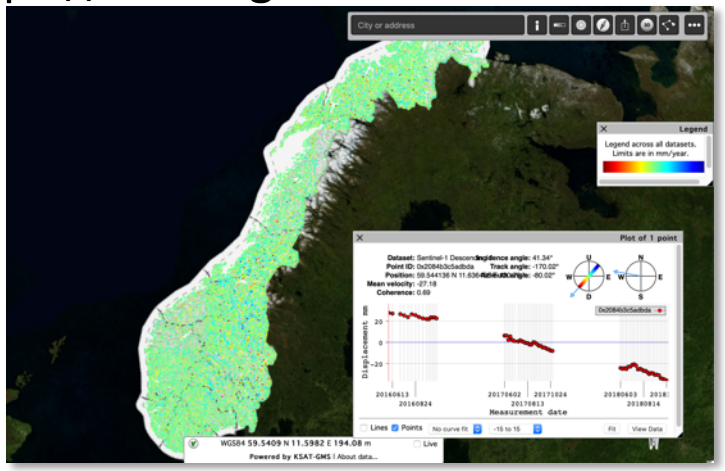


Oslo center

Analysis of InSAR images between 2009 and today reveals more than one centimeter per year of subsidence in the Bjørvika area.

From Geological Survey of Norway:
https://www.ngu.no/en/topic/insar-norway

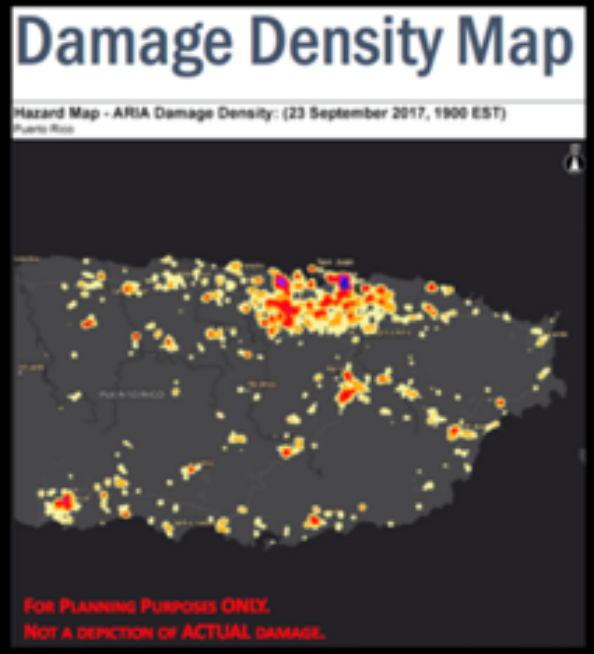
- NGU uses free and open Sentinel 1 data acquired over Norway every 6 days
- Funded to create a national deformation map, to make data easily available to everyone.
- Primarily used for identifying areas prone to landslides
- Has online clickable map that shows both velocities and time series for points: https://insar.ngu.no



Using InSAR for Mapping Damage: 2017 Hurricane Maria

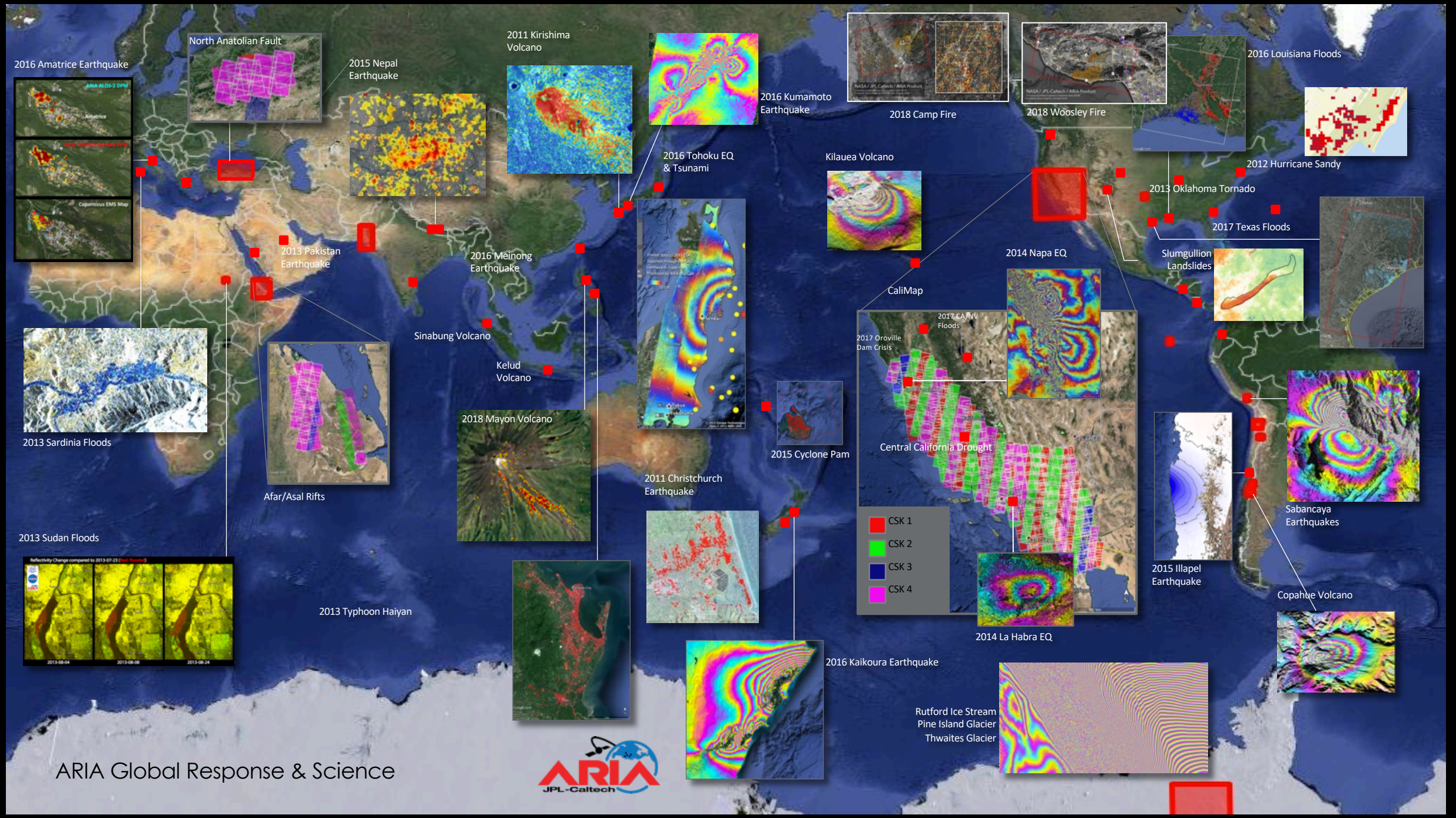
Hurricane Maria

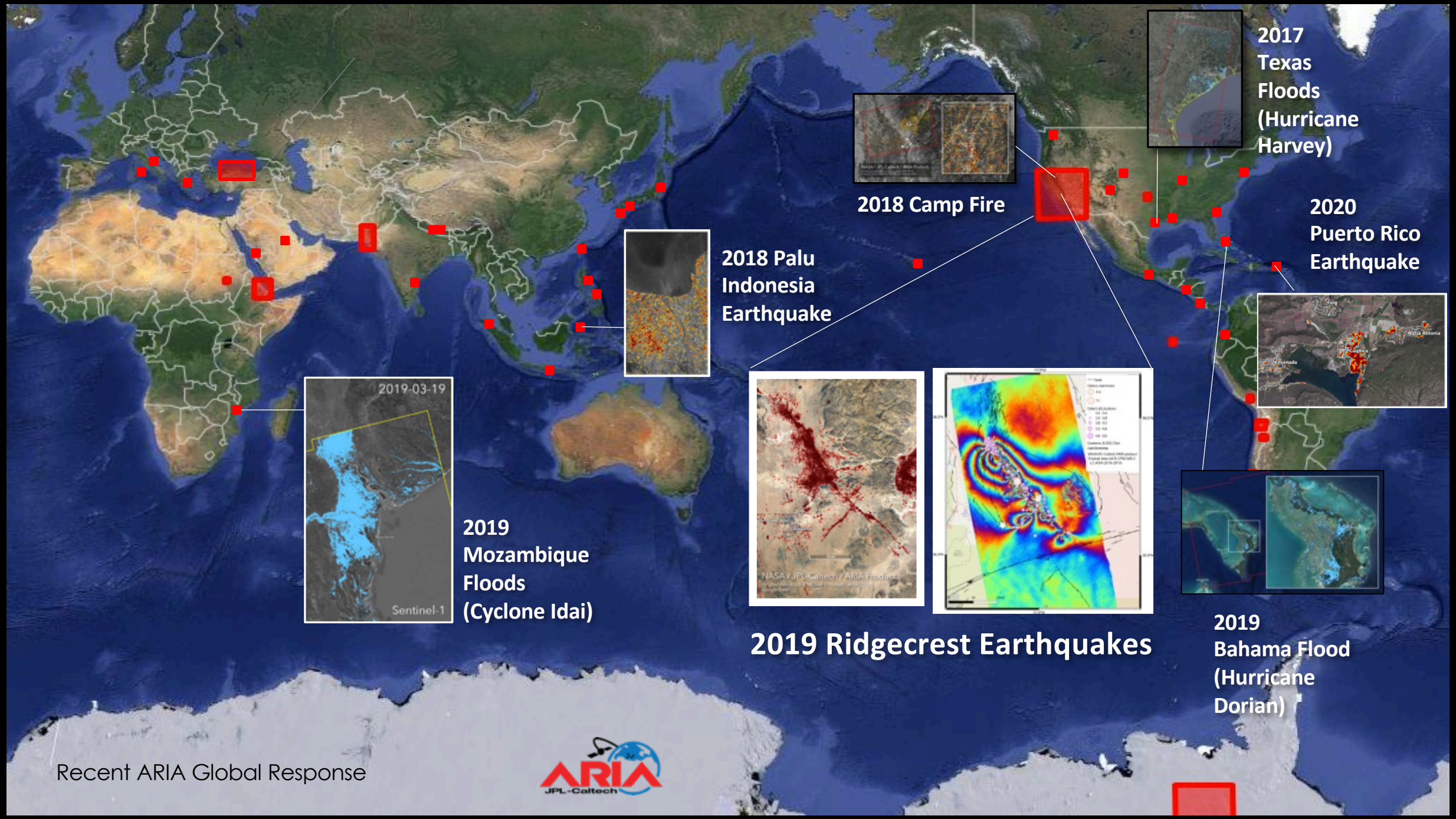
Damage Proxy Map for Puerto Rico, Hurricane Maria Response



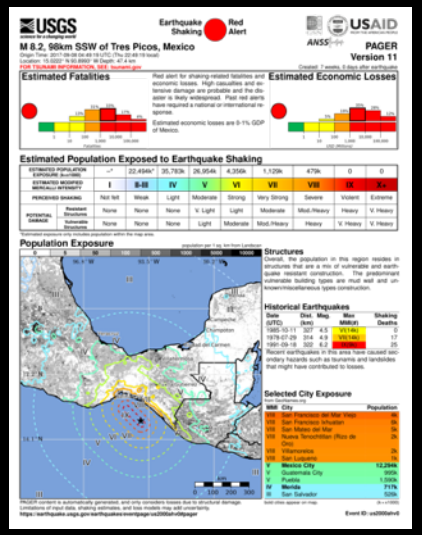
FEMA

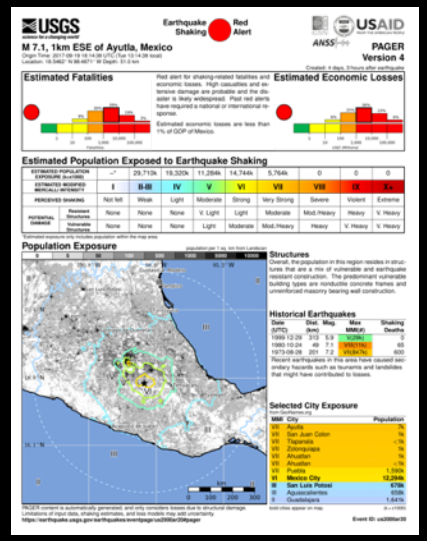
FEMA used ARIA product to generate Damage Density Map

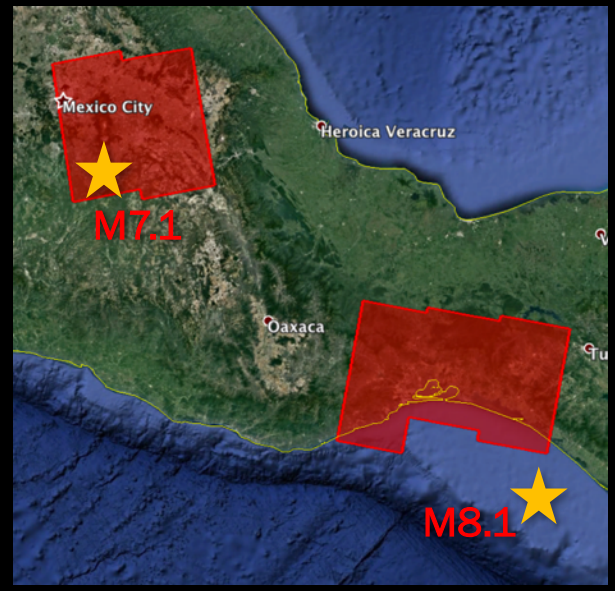

2016 Amatrice Earthquake
North Anatolian Fault
2015 Nepal Earthquake
2011 Kirishima Volcano
2016 Kumamoto Earthquake
2018 Camp Fire
2018 Woosley Fire
2016 Louisiana Floods
2012 Hurricane Sandy
2016 Tohoku EQ & Tsunami
Kilauea Volcano
2013 Oklahoma Tornado
2017 Texas Floods
2013 Pakistan Earthquake
2016 Meinong Earthquake
2014 Napa EQ
Slumgullion Landslides
CaliMap
2017 CA/NV Floods
2017 Oroville Dam Crisis
Sinabung Volcano
Kelud Volcano
2013 Sardinia Floods
2018 Mayon Volcano
2015 Cyclone Pam
Central California Drought
CSK 1
CSK 2
CSK 3
CSK 4
Afar/Asal Rifts
2011 Christchurch Earthquake
Sabancaya Earthquakes
2015 Illapel Earthquake
2013 Sudan Floods
2013 Typhoon Haiyan
2014 La Habra EQ
Copahue Volcano
2016 Kaikoura Earthquake
Rutford Ice Stream
Pine Island Glacier
Thwaites Glacier
ARIA Global Response & Science
ARIA
JPL-Caltech


2017
Texas
Floods
(Hurricane
Harvey)
2018 Camp Fire
2020
Puerto Rico
Earthquake
2018 Palu
Indonesia
Earthquake
2019-03-19
Sentinel-1
2019
Mozambique
Floods
(Cyclone Idai)
NASA / JPL-Caltech / ARIA Products
2019 Ridgecrest Earthquakes
2019
Bahama Flood
(Hurricane
Dorian)
Recent ARIA Global Response
ARIA
JPL-Caltech

Damage Assessments for 2017 Mexico Earthquakes







9/7 (local)
M8.2 quake

9/17
DPM

9/19
M7.1

9/20
DPM

9/9
First ALOS-2
acquisition

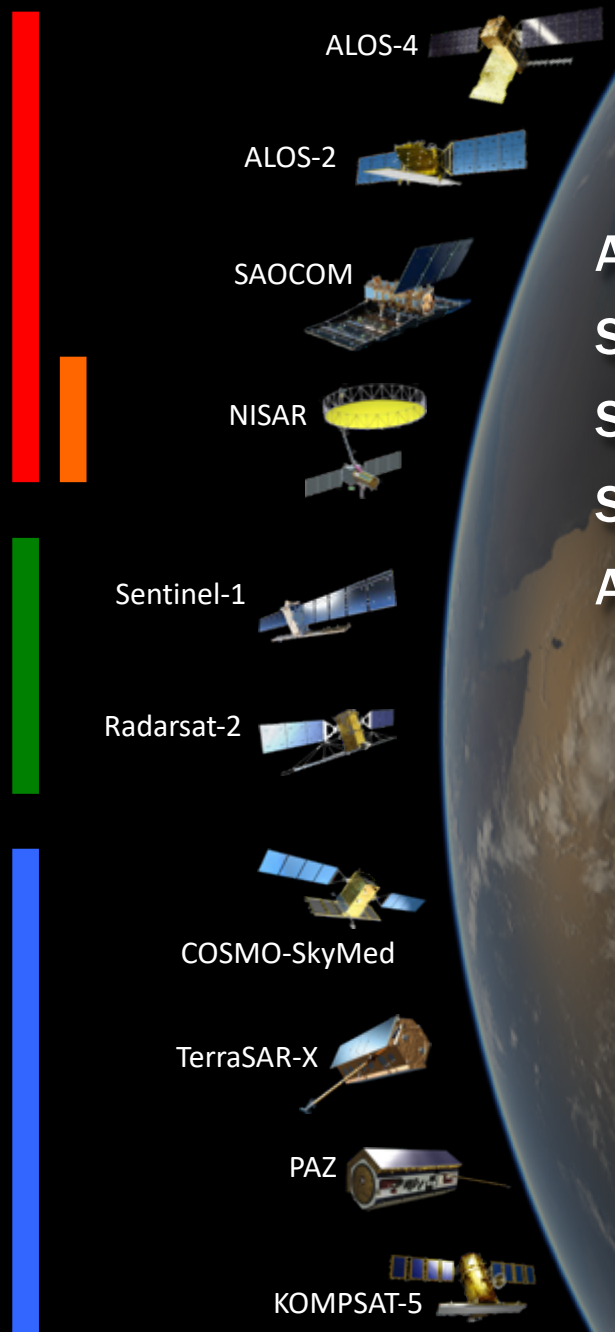
9/13
First
Copernicus
Sentinel-1
acquisition

9/20
First
Copernicus
Sentinel-1
acquisition

ARIA damage maps and ground deformation map for the M8.1 and M7.1 earthquakes in Mexico

Figures: Sang-Ho Yun

How fast can we get the SAR data?



All missions: 6 h

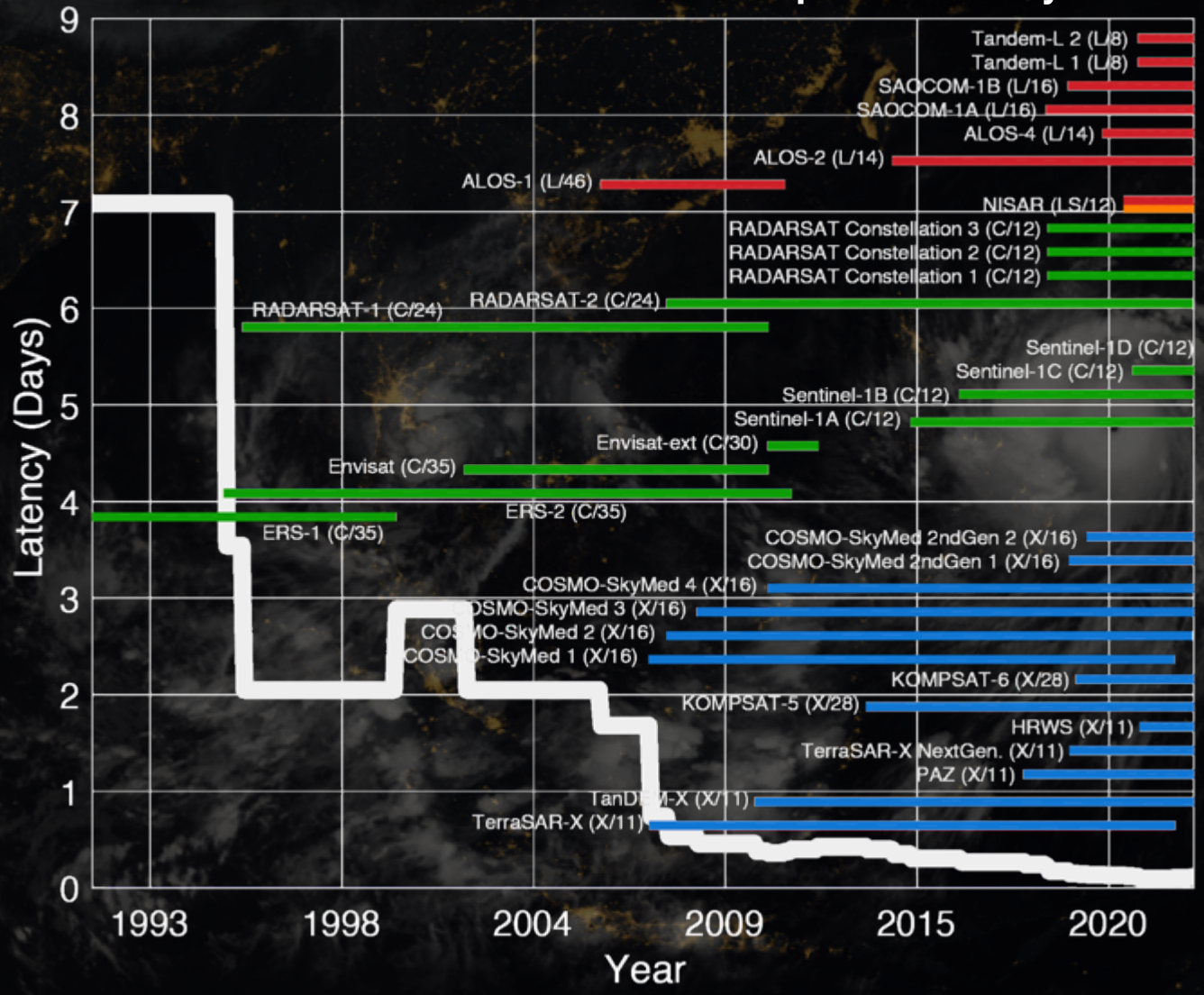
S1 & A2 & CSK: 10 h

S1 & A2: 20 h

S1: 30 h

A2: 2.8 days

International SAR Satellites Overpass Latency



From Sang-Ho Yun

Can we provide data faster?

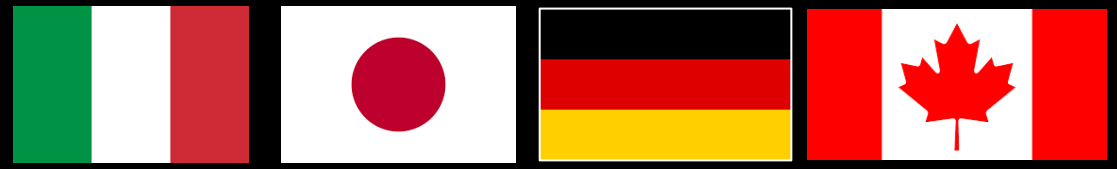
- Further automate processing
- Machine learning for precursor detection, improved damage & flood mapping
- Faster processing (GPU's)
- Faster access to more data

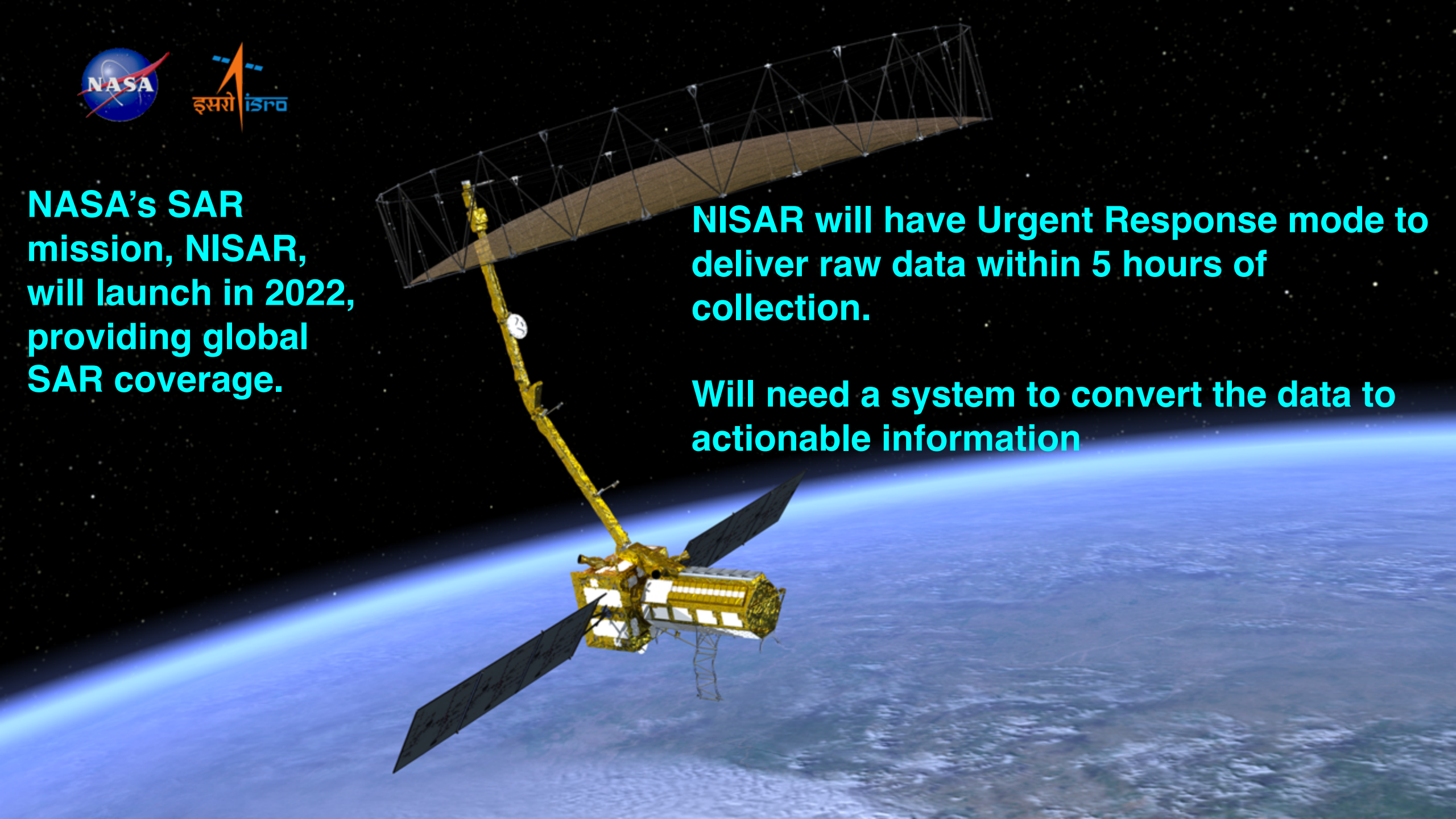
SAR Missions with Free and Open data policy

ESA Copernicus
Sentinel 1a & 1b

SAR Missions w/out Free and Open data policy

- Italy - ASI Cosmo-SkyMed
- Japan - JAXA ALOS-2
- Germany - DLR TerraSAR-X
- Canada - CSA Radarsat-2




NASA’s SAR mission, NISAR, will launch in 2022, providing global SAR coverage.
NISAR will have Urgent Response mode to deliver raw data within 5 hours of collection.
Will need a system to convert the data to actionable information

Leveraging international partnership interest to improve system.

We have cloned the ARIA system in Singapore, to collaborate on disaster response and algorithm development.

Slide: Sang-Ho Yun

Summary

- There is much more SAR data available now than in the past – and that will keep improving
- NASA and other space agencies are planning long-term for future SAR missions -> moving towards continuity of observations.
- Applications are being developed for disaster damage mapping
- Applications are also being developed for deformation monitoring
- Latency and temporal resolution is still a limiting factor for ‘near-real-time’ rapid response applications