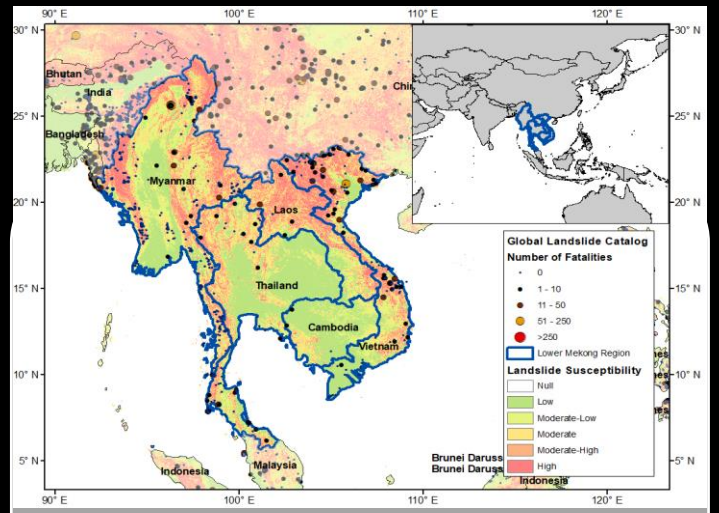
Global Open-Source Tools to Support Landslide Hazard and Impact Assessm

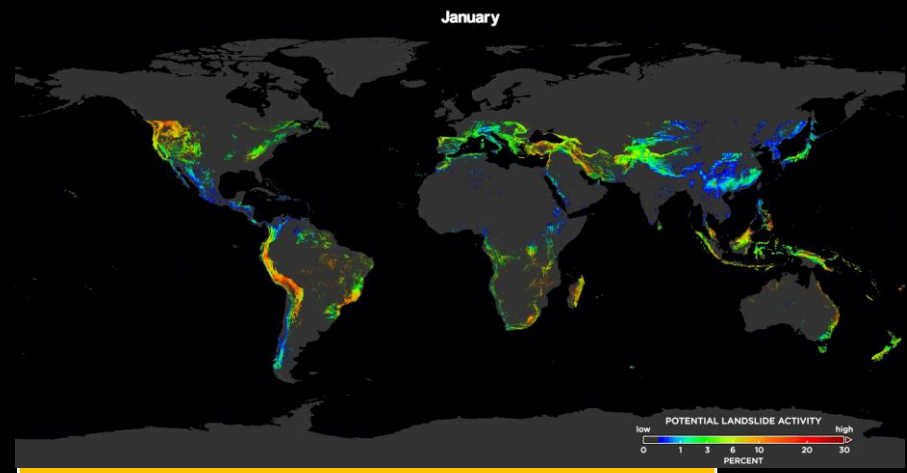
Dalia Kirschbaum, PhD
Thomas Stanley (UMBC/NASA)
Robert Emberson (UMBC/NASA)
Pukar Amatya (UMBC/NASA)
Sana Khan (U of Maryland/ NASA)
Eli Orland (UMBC/NASA)

Landslide Modeling: A multi-scale approach

Local landslide mapping, slope-stability modeling and Land Surface Modeling



Regional landslide modeling & mapping



Global rainfall-triggered landslide hazard characterization (LHASA)

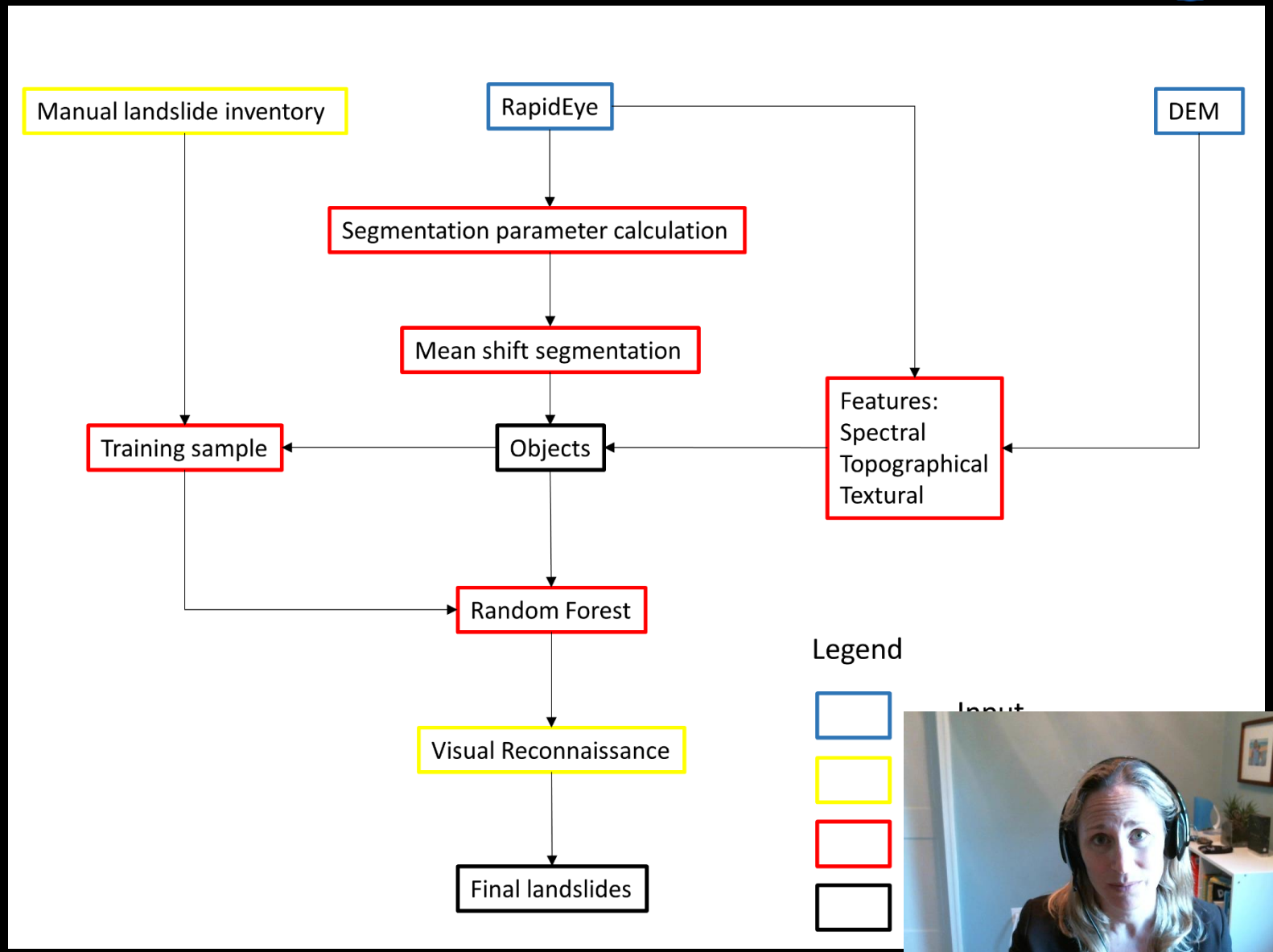
Local ← Regional → Global

Landslide Mapping: Semi-Automatic Landslide Detection (SALaD) system

Programming: Python

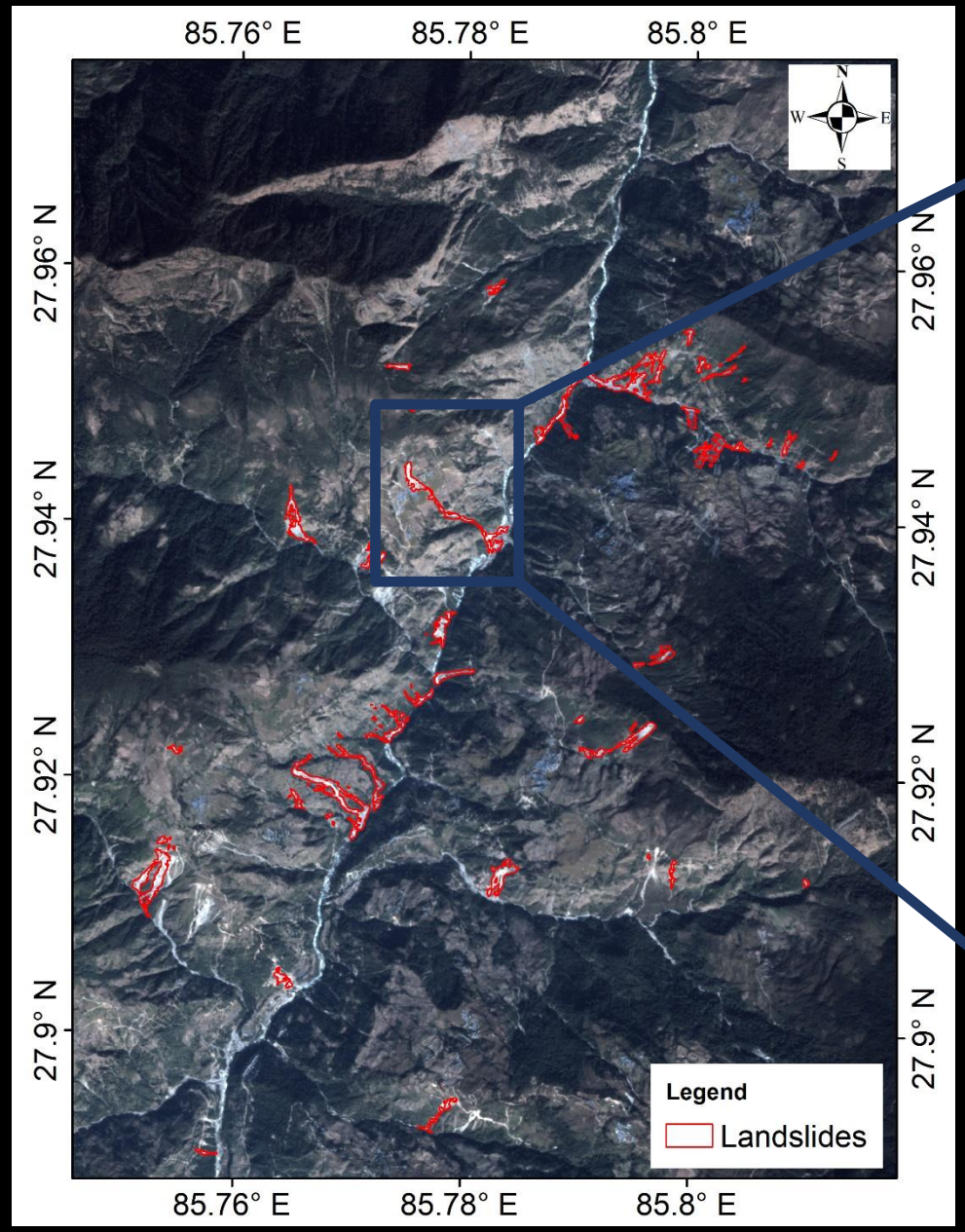
Operating System: Linux or Windows

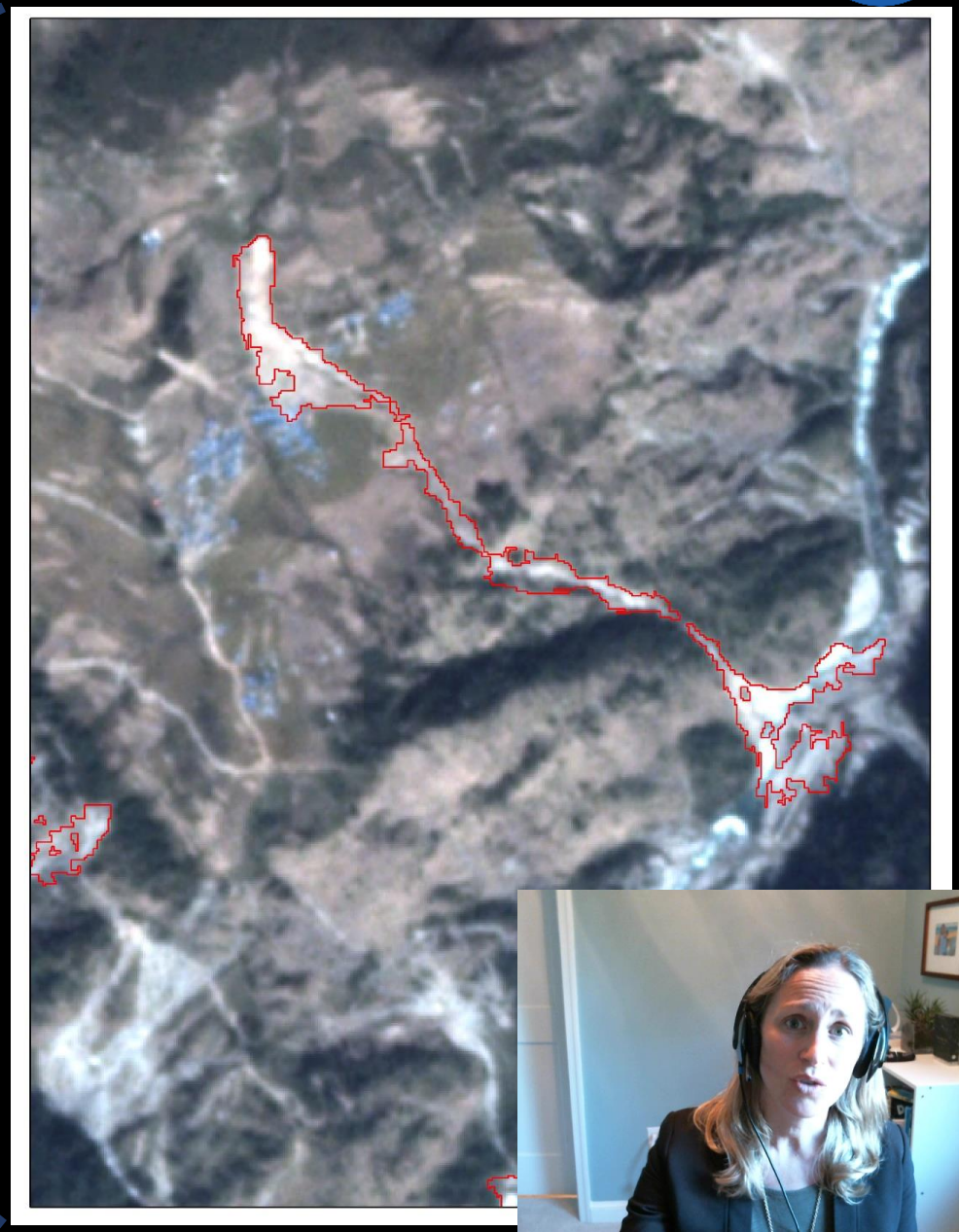
Currently configured in NCCS ADAPT Linux platform



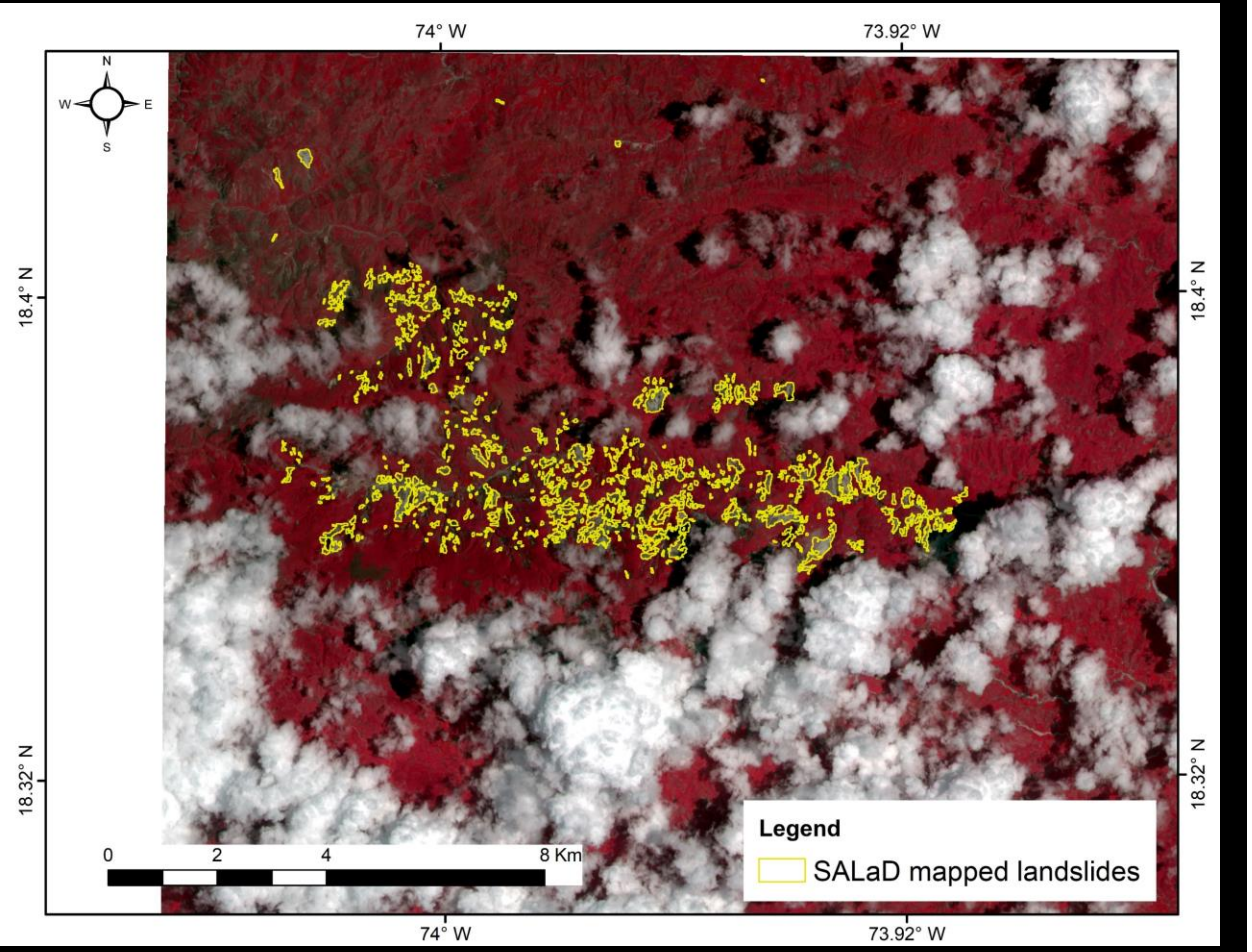
Amatya et al. 2021

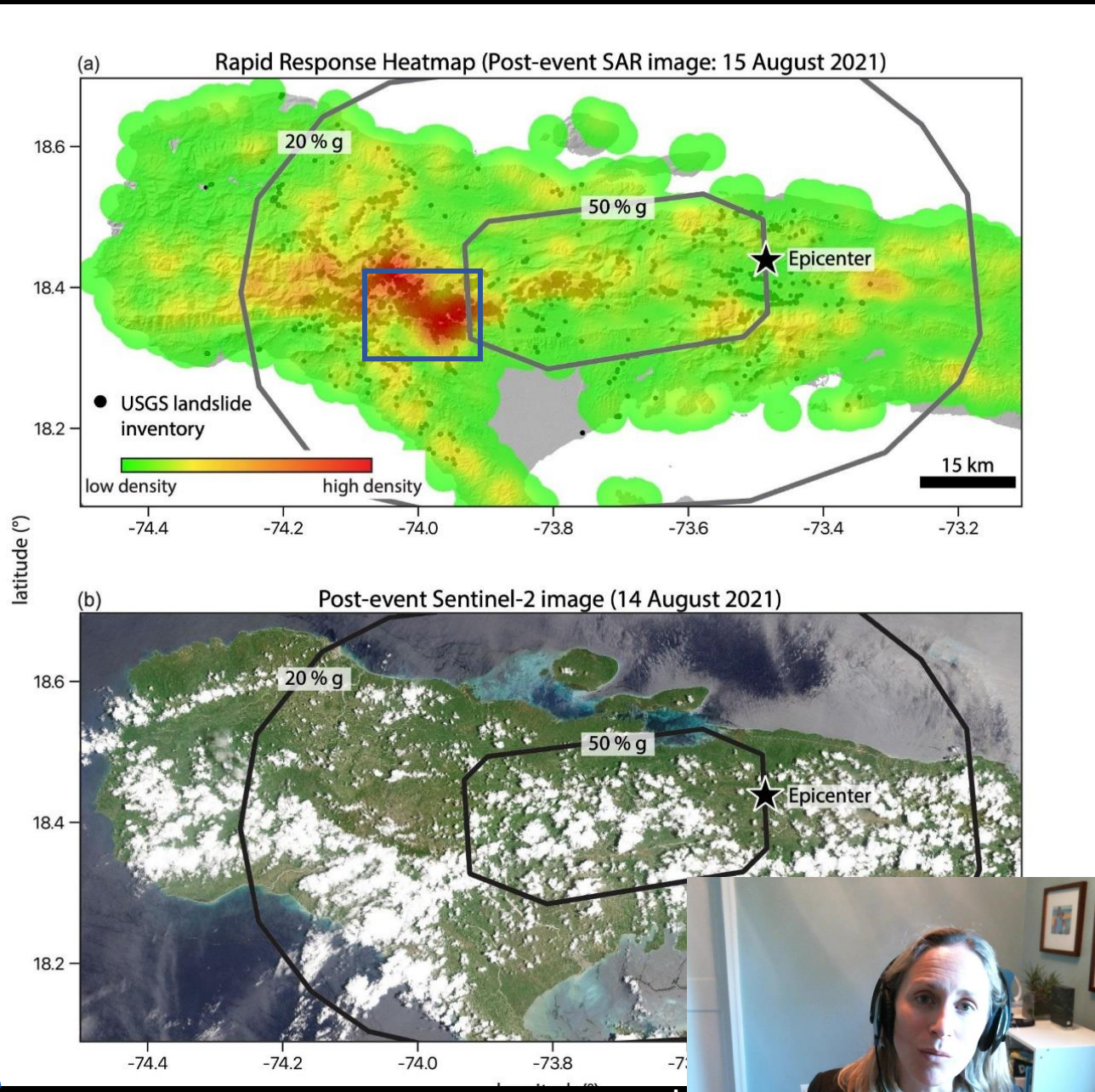
Lidi landslide, Sindupalchowk, Nepal (August 14, 2020)





2021 Haiti Earthquake and Landslide Mapping





https://maps.disasters.nasa.gov/arcgis/home/item.html?id=e34b9f8f6f774d6ca2f6ae6ad3d8b21b

https://nhess.copernicus.org

LHASA 2.0 Structure

Static Factors
DEM
Geology
Rock strength

Triggers
Satellite NRT rainfall
Rainfall Forecast
Soil Moisture
Snow depth

Post-fire Debris Flow Module

Landslide Nowcast & Forecasts:
Probability of
- Rainfall-triggered landslides
- Post-fire debris flows

Methodology:
machine-learning model trained with different types of landslide data

Exp
P
Int

LHASA 2.0 Nowcast dynamic variables

SMAP L4 has a 3-day latency, so need to fill gap with IMERG.

Antecedent conditions represent year-to-date

- Daily
  - (but can be produced 48x/day)
- 30-arcsecond
- Global land surface from 60 North to 60 South
  - (optional subsetting)
- Probabilistic (continuous data between 0 and 1)
- 0.5 GB after compression

Soil Wetness = Full-profile Soil Moisture / Porosity SMAP L4

Snow Depth SMAP L4

Antedent Rainfall = $\sum_{t=-1}^{-2} rain$

IMERG Late NRT

Current Daily Rainfall Total

IMERG Early NRT

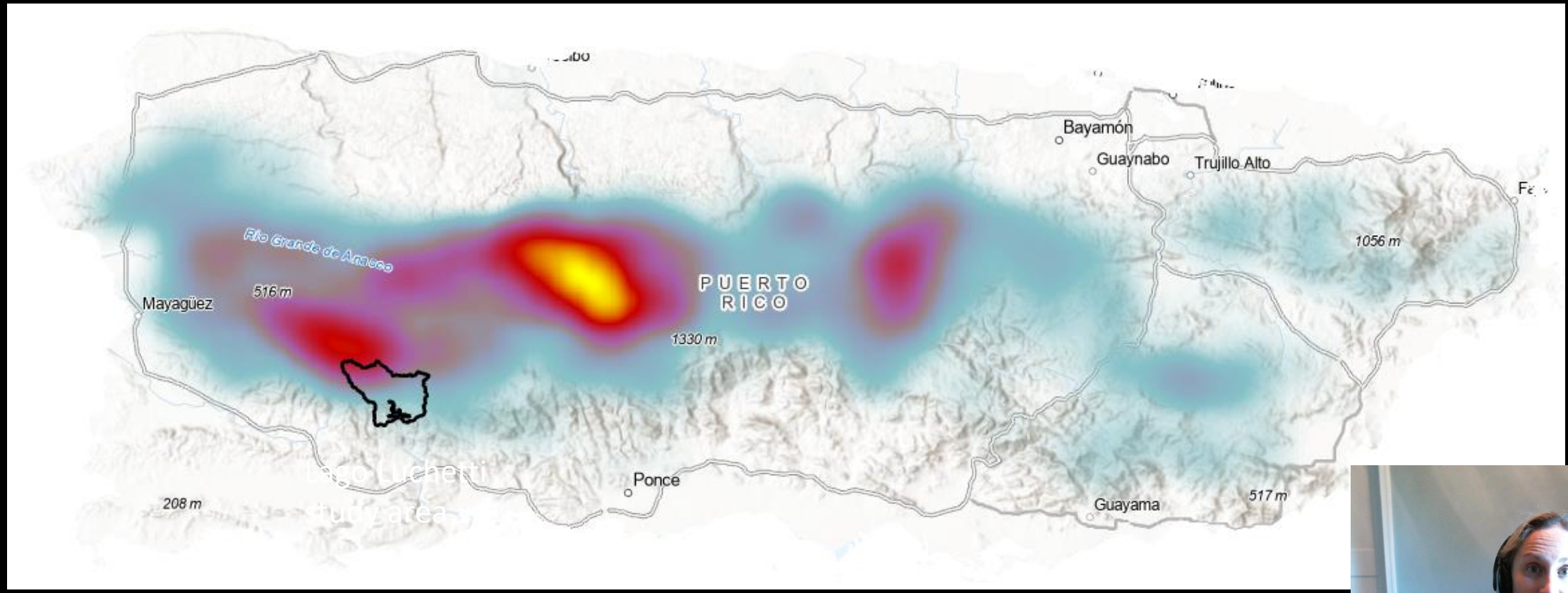
Fore-casted Precip 24 h+

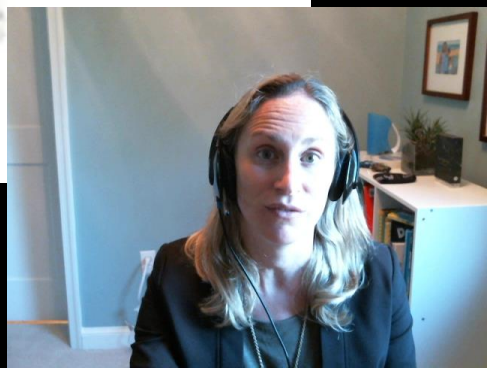
GMAO FP

						t=-2	Yesterday	Today (t

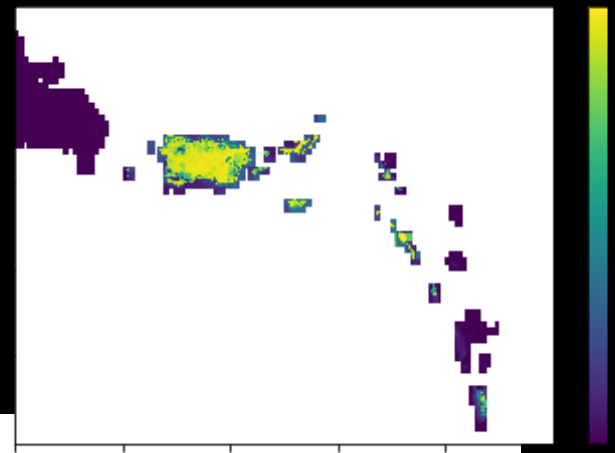
Stanley et al. 2021

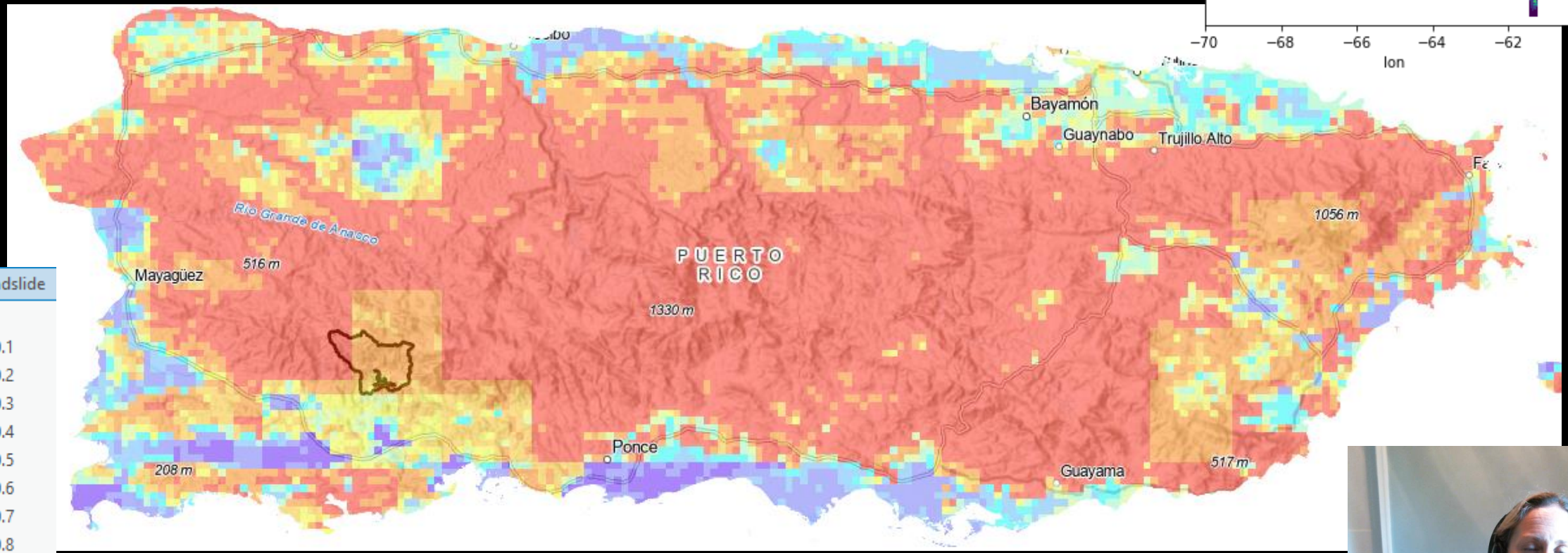
Hurricane Maria: 2017 – September Landslide density

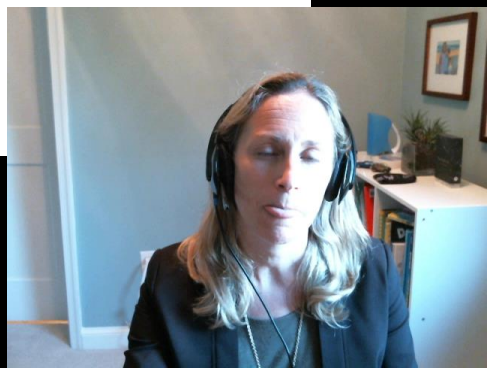




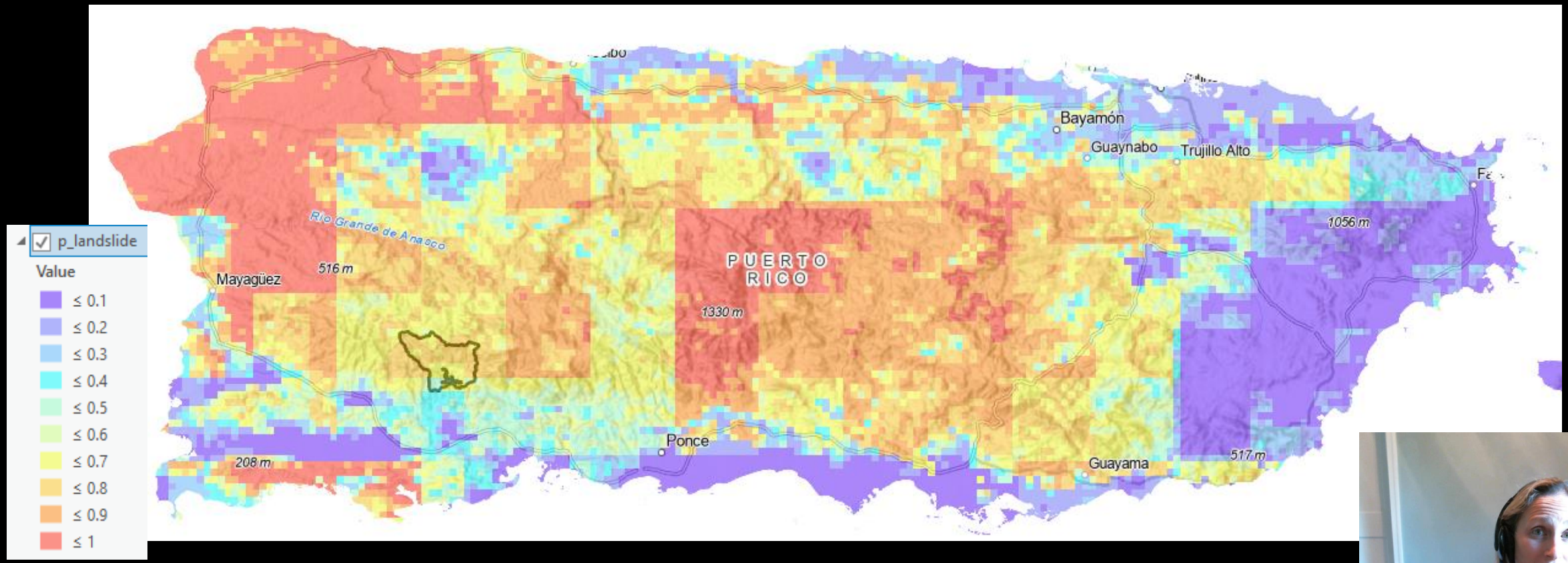
Hurricane Maria: LHASA-NRT 2017-9-20 (UTC)



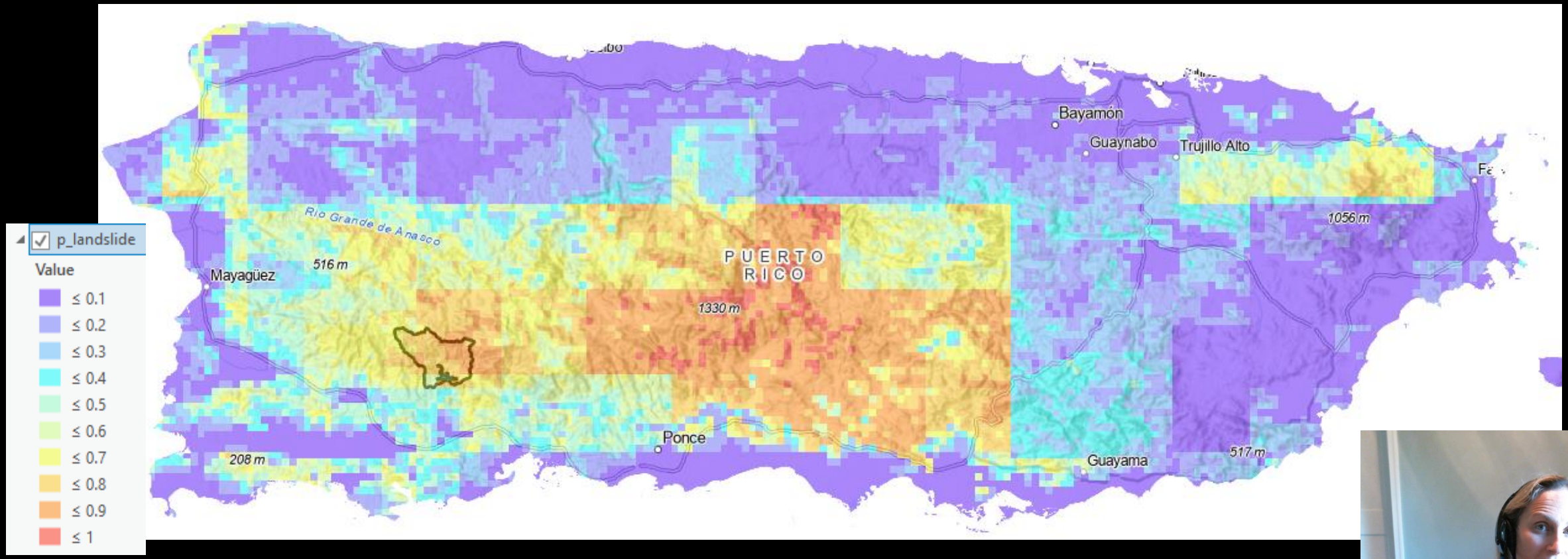


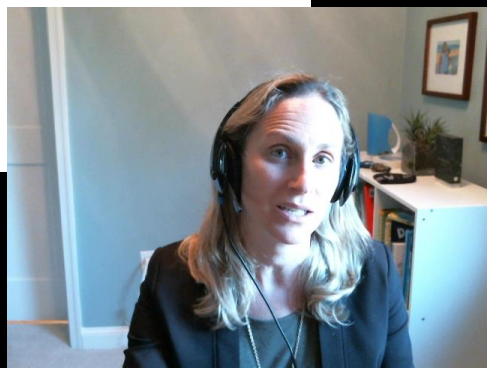


Hurricane Maria: LHASA-NRT 2017-9-21 (UTC)

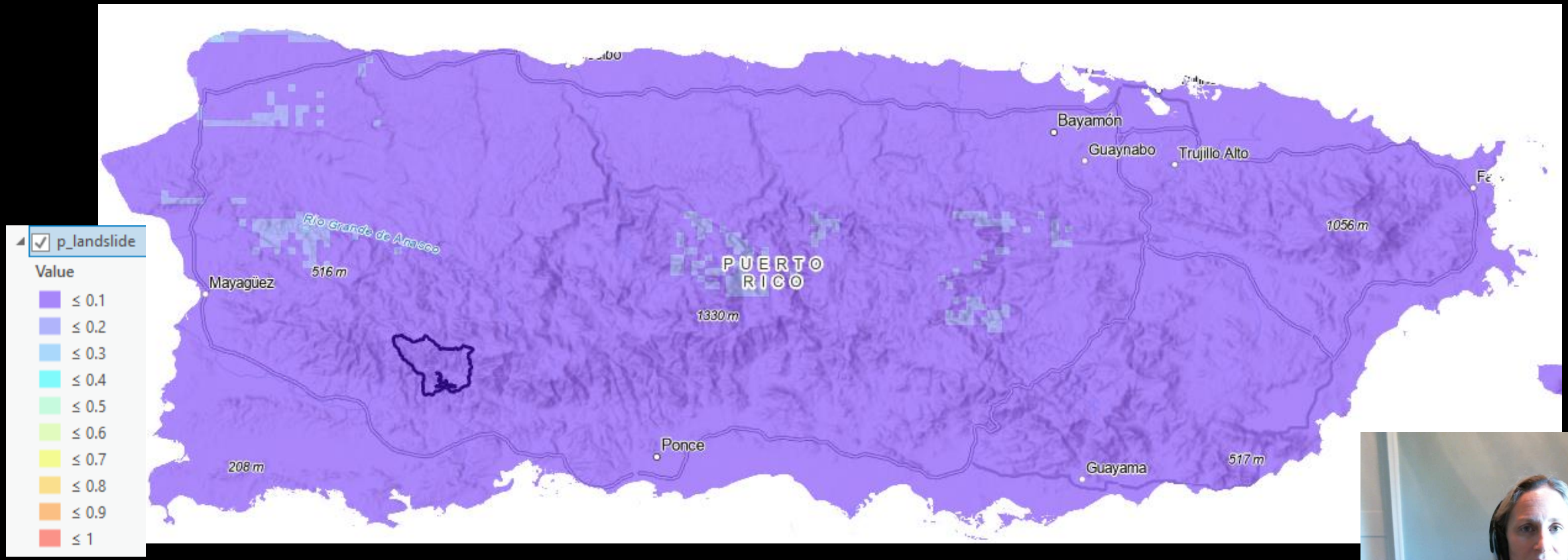


Hurricane Maria: LHASA-NRT 2017-9-22 (UTC)



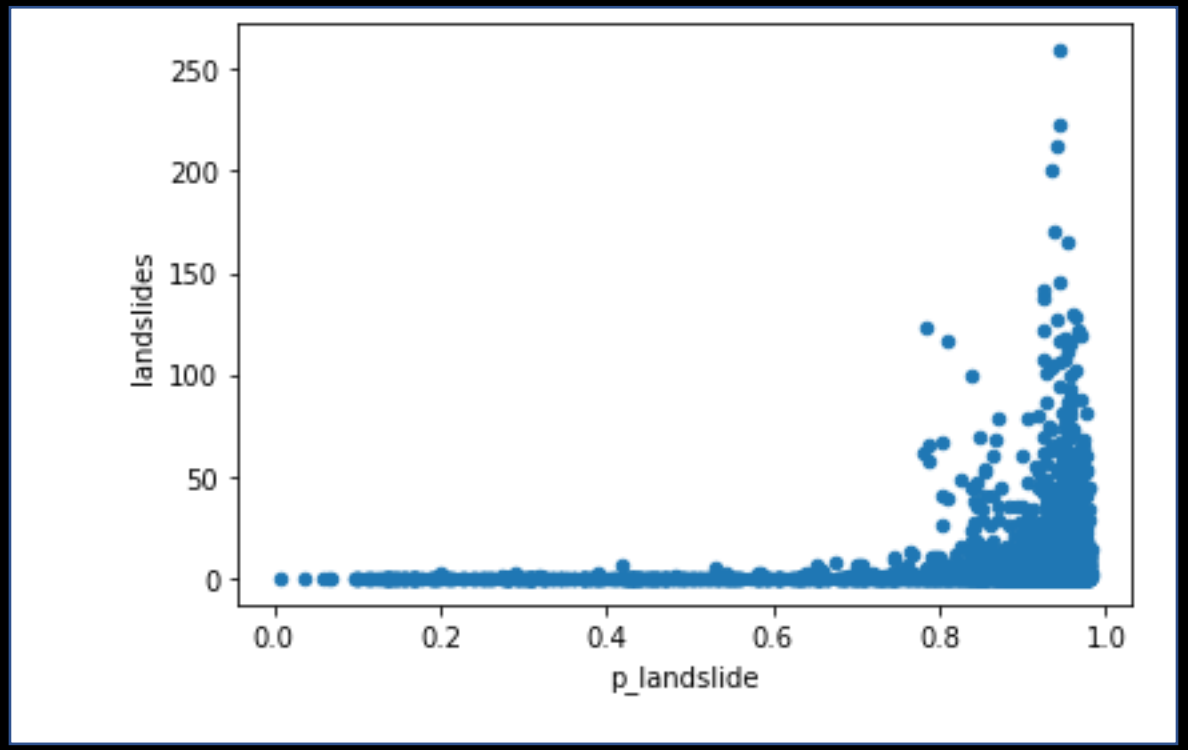


Hurricane Maria: LHASA-NRT 2017-9-23 (UTC)

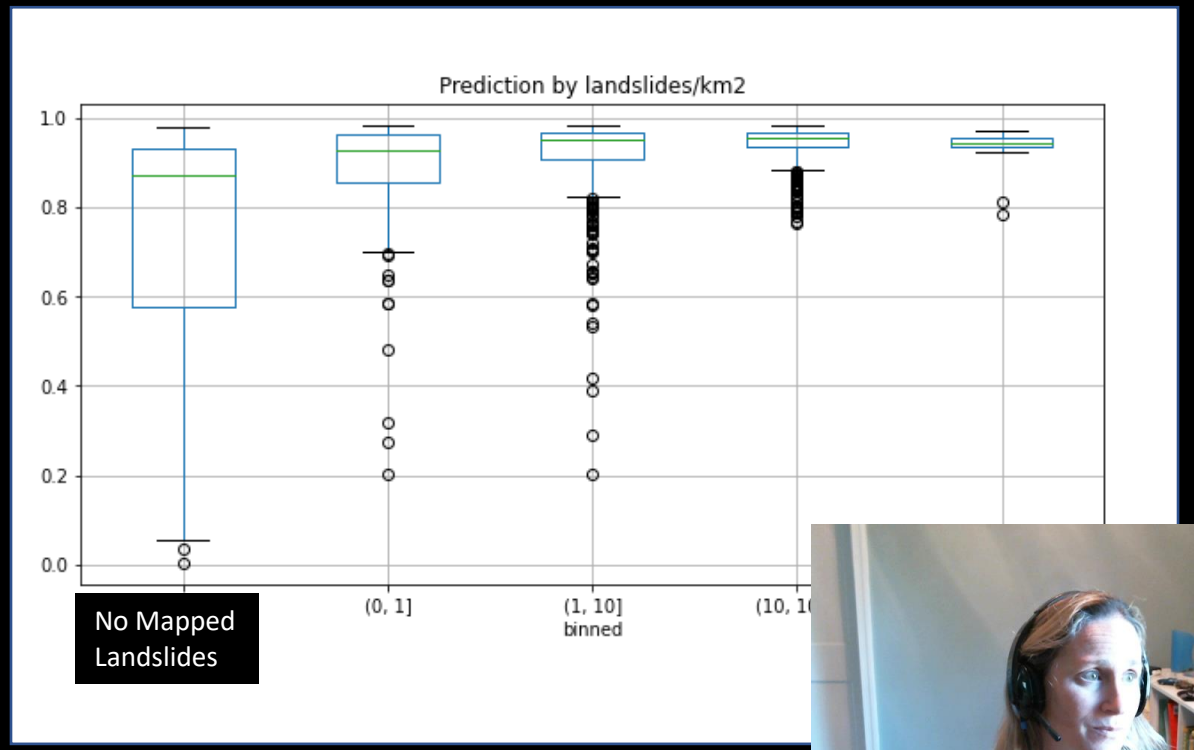


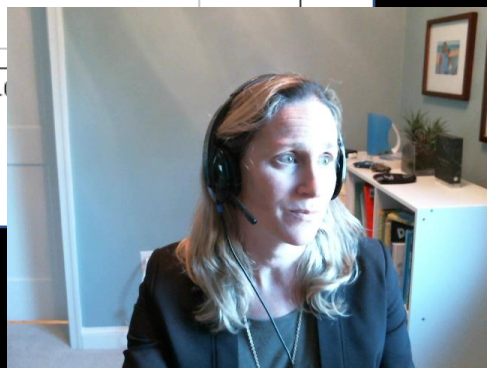
Hurricane Maria: LHASA-NRT 2017-9-20 (UTC)

Big groups of landslides are well predicted.

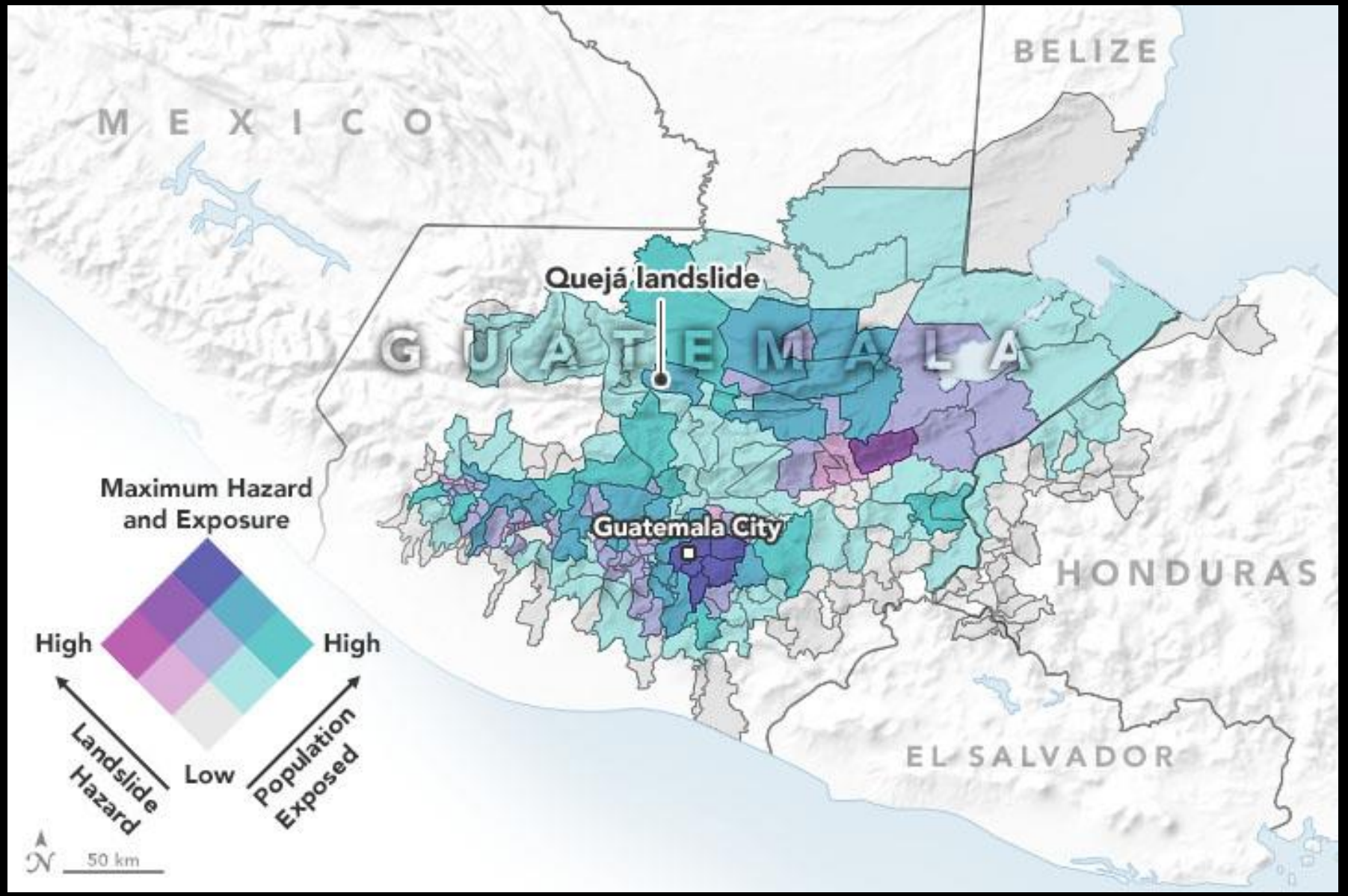


Higher certainty for big clusters of landslides.



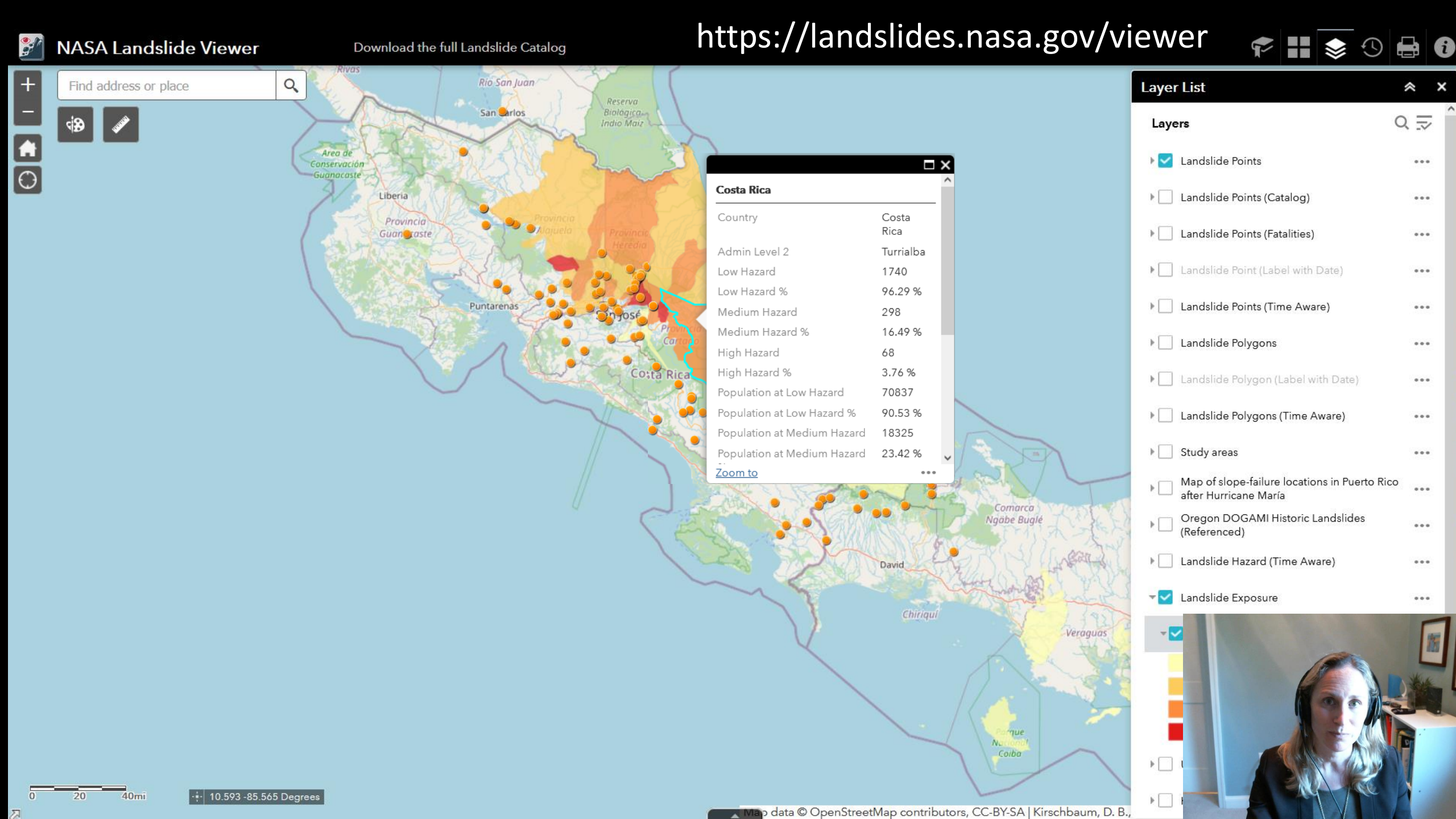


Mapping Exposure from Eta

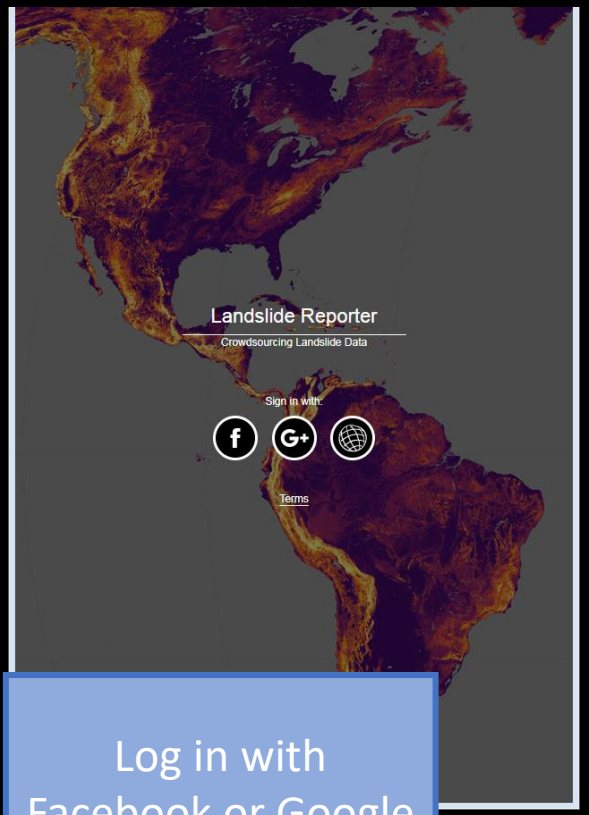


Combined LHASA landslide hazard estimates with population exposure we can summarize the storm's potential impact by administrative district

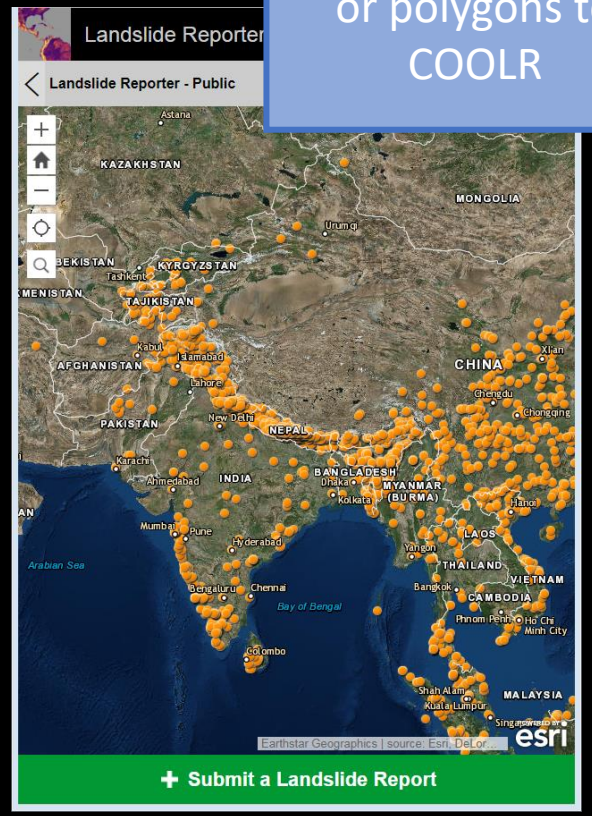
Embers


NASA Landslide Viewer
Download the full Landslide Catalog
https://landslides.nasa.gov/viewer
Find address or place
Costa Rica
Country Costa Rica
Admin Level 2 Turrialba
Low Hazard 1740
Low Hazard % 96.29 %
Medium Hazard 298
Medium Hazard % 16.49 %
High Hazard 68
High Hazard % 3.76 %
Population at Low Hazard 70837
Population at Low Hazard % 90.53 %
Population at Medium Hazard 18325
Population at Medium Hazard 23.42 %
Zoom to
Layer List
Layers
Landslide Points
Landslide Points (Catalog)
Landslide Points (Fatalities)
Landslide Point (Label with Date)
Landslide Points (Time Aware)
Landslide Polygons
Landslide Polygon (Label with Date)
Landslide Polygons (Time Aware)
Study areas
Map of slope-failure locations in Puerto Rico after Hurricane María
Oregon DOGAMI Historic Landslides (Referenced)
Landslide Hazard (Time Aware)
Landslide Exposure
Rivas
Rio San Juan
San Carlos
Reserva Biológica Indio Maiz
Area de Conservación Guanacaste
Liberia
Provincia Alajuela
Provincia Heredia
Puntarenas
San José
Provincia Cartago
Costa Rica
Comarca Ngäbe Buglé
David
Chiriquí
Veraguas
0 20 40mi
10.593 -85.565 Degrees
Map data © OpenStreetMap contributors, CC-BY-SA | Kirschbaum, D. B.,

Landslide data needed!



Log in with Facebook or Google

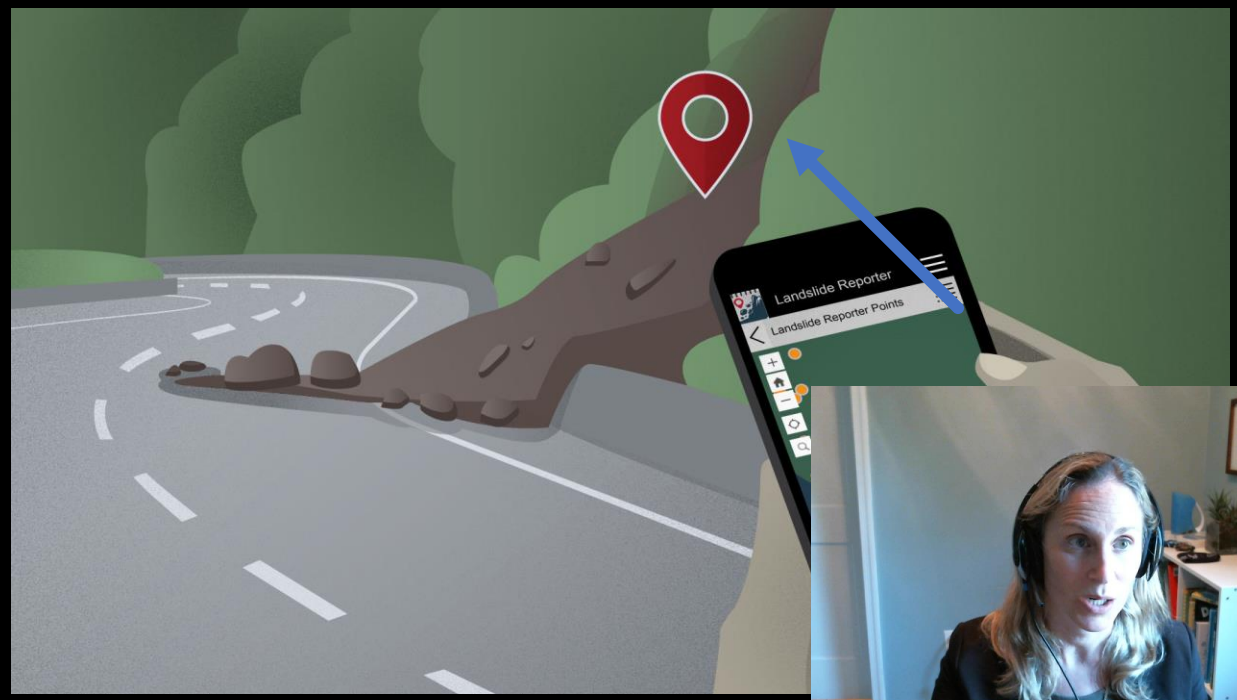


Submit new points or polygons to COOLR

Landslide Reporter

https://landslides.nasa.gov

Citizen scientists are helping NASA expand the global map of landslides, one landslide event at a time!



LandAware Network: https://www.landaware.org/

LandAware is a multi-disciplinary, knowledge-based, non-profit network of individuals (e.g. managers, researchers, stakeholders) who are interested in cooperating for addressing and promoting issues related to **Landslide Early Warning Systems** (LEWS). The primary purpose of LandAware is to share experiences, needs and innovations among LEWS experts and to develop and promote guidelines and best practices for upcoming LEWS.

Data Working Group

Co-Chairs: Dalia Kirschbaum (NASA), Ben Mirus (US Geological Survey)

Goal: To promote open data and sharing of information that can be used for landslide model development, parameterization, or evaluation.

Satellite data, models and the view forward with landslides

Google Earth Engine

aws

planet.

DigitalGlobe

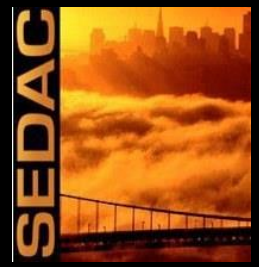
SENTINEL 2

Landslide/debris flow mapping

Landslide modeling and forecasting

Exposure analysis

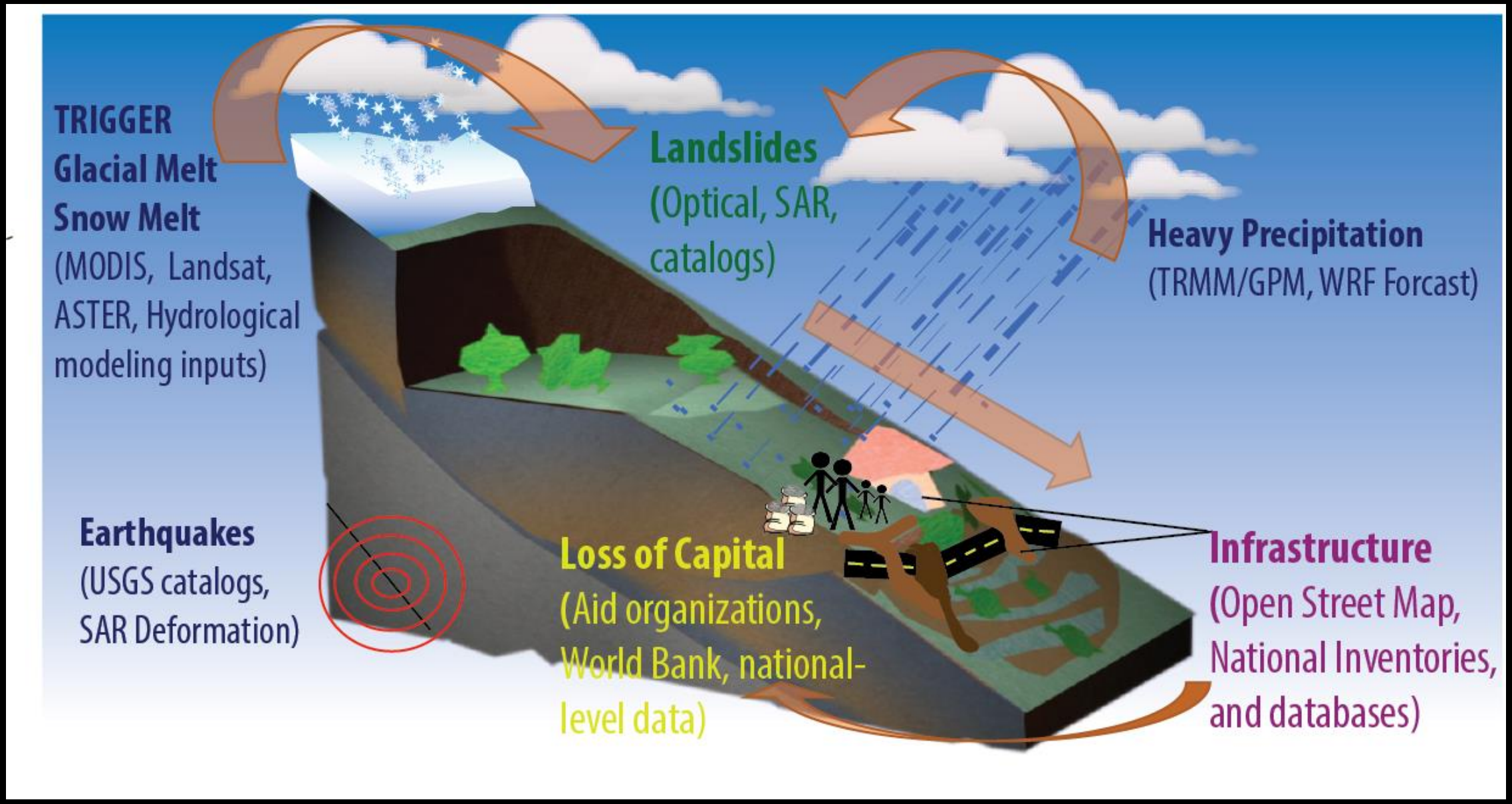
全球降水観測計画
GPM
GLOBAL PRECIPITATION MEASUREMENT



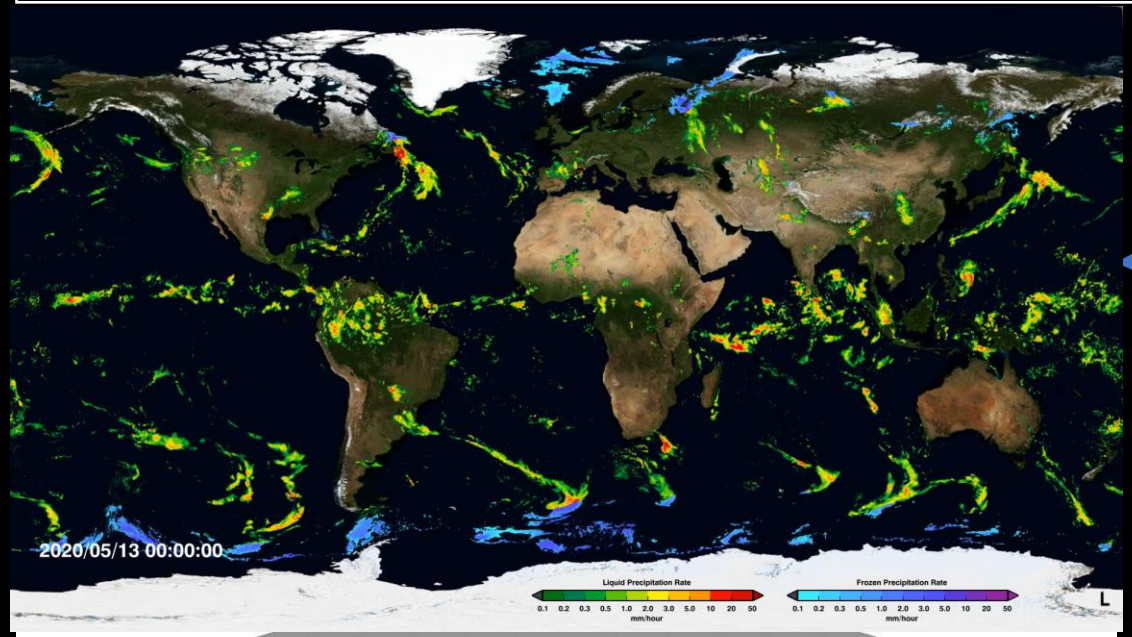
References: https://landslides.nasa.gov

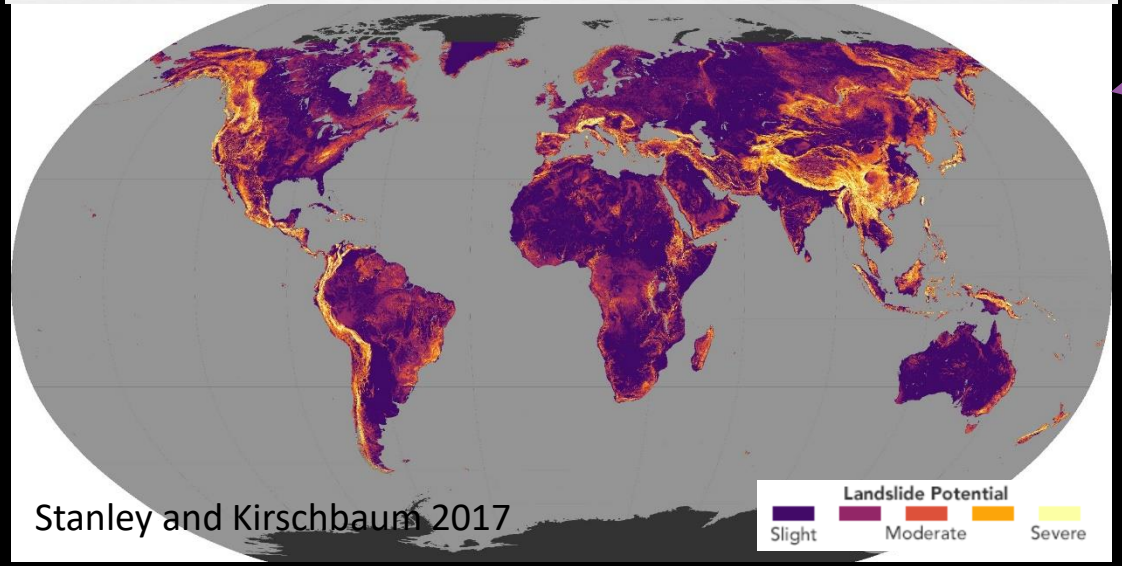
- Amatya, P., Kirschbaum, D., Stanley, T. & Tanyas, H. 2021. “Landslide mapping using object-based image analysis and open source tools.” *Engineering Geology.* 282.
- Emberson, R., Kirschbaum, D. & Stanley, T. 2021. “Global connections between El Nino and landslide impacts.” *Nature Communications.* 12.
- Emberson, R., Kirschbaum, D. & Stanley, T. 2020. “New global characterisation of landslide exposure.” *Natural Hazards and Earth System Science.* 20, 3413–3424.
- Handwerger, A. L., Jones, S. Y., Amatya, P., Kerner, H. R., Kirschbaum, D. B., and Huang, M-H. 2022. “Strategies for landslide detection using open-access synthetic aperture radar backscatter change in Google Earth Engine.” *Natural Hazards and Earth Systems Science*.
- Kirschbaum, D., and T. Stanley. 2018. "Satellite-Based Assessment of Rainfall-Triggered Landslide Hazard for Situational Awareness." *Earth's Future*.
- Stanley, T. A., D. B. Kirschbaum, G. Benz, et al. 2021. “Data-Driven Landslide Nowcasting at t
Scale.” *Frontiers in Earth Science*, 9.

Tools and Data for Observing Landslides

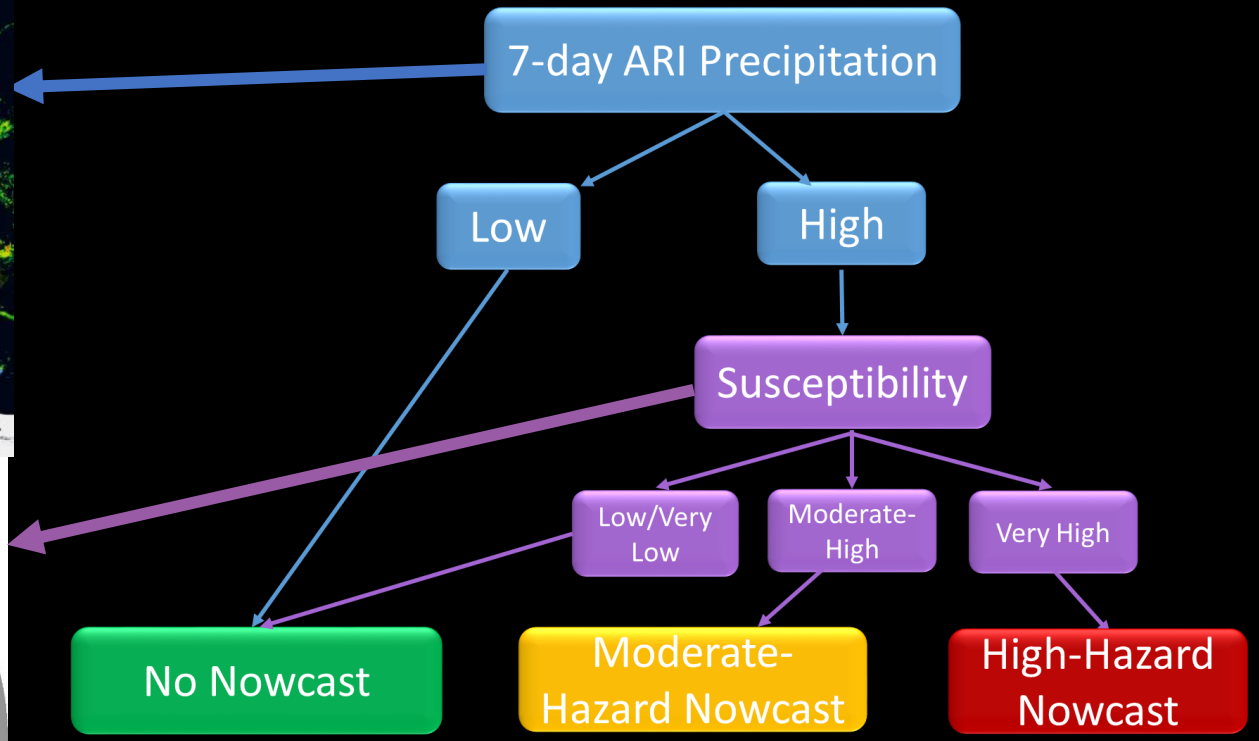


LHASA: Landslide Hazard Assessment Model for Situational Awareness



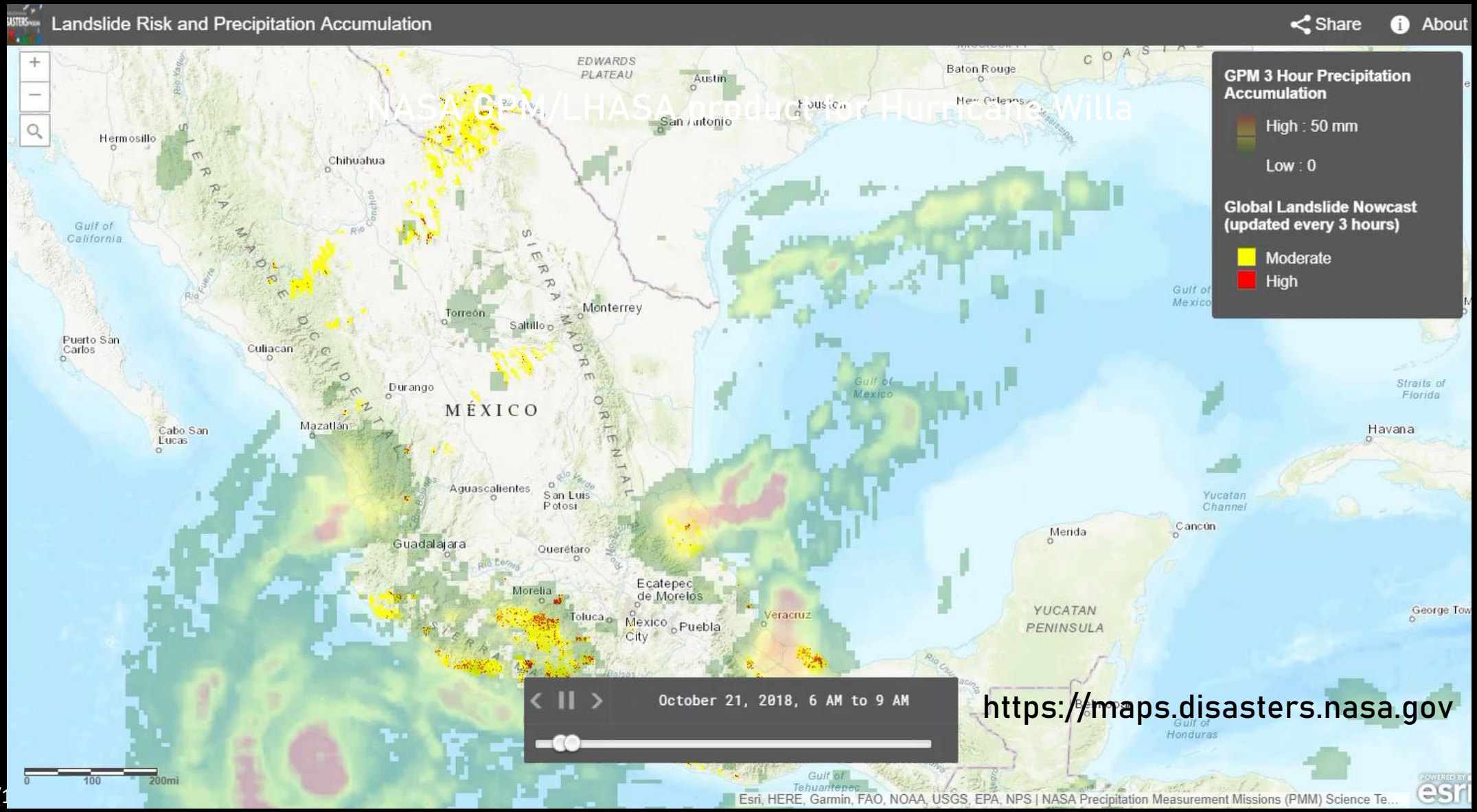


Stanley and Kirschbaum 2017

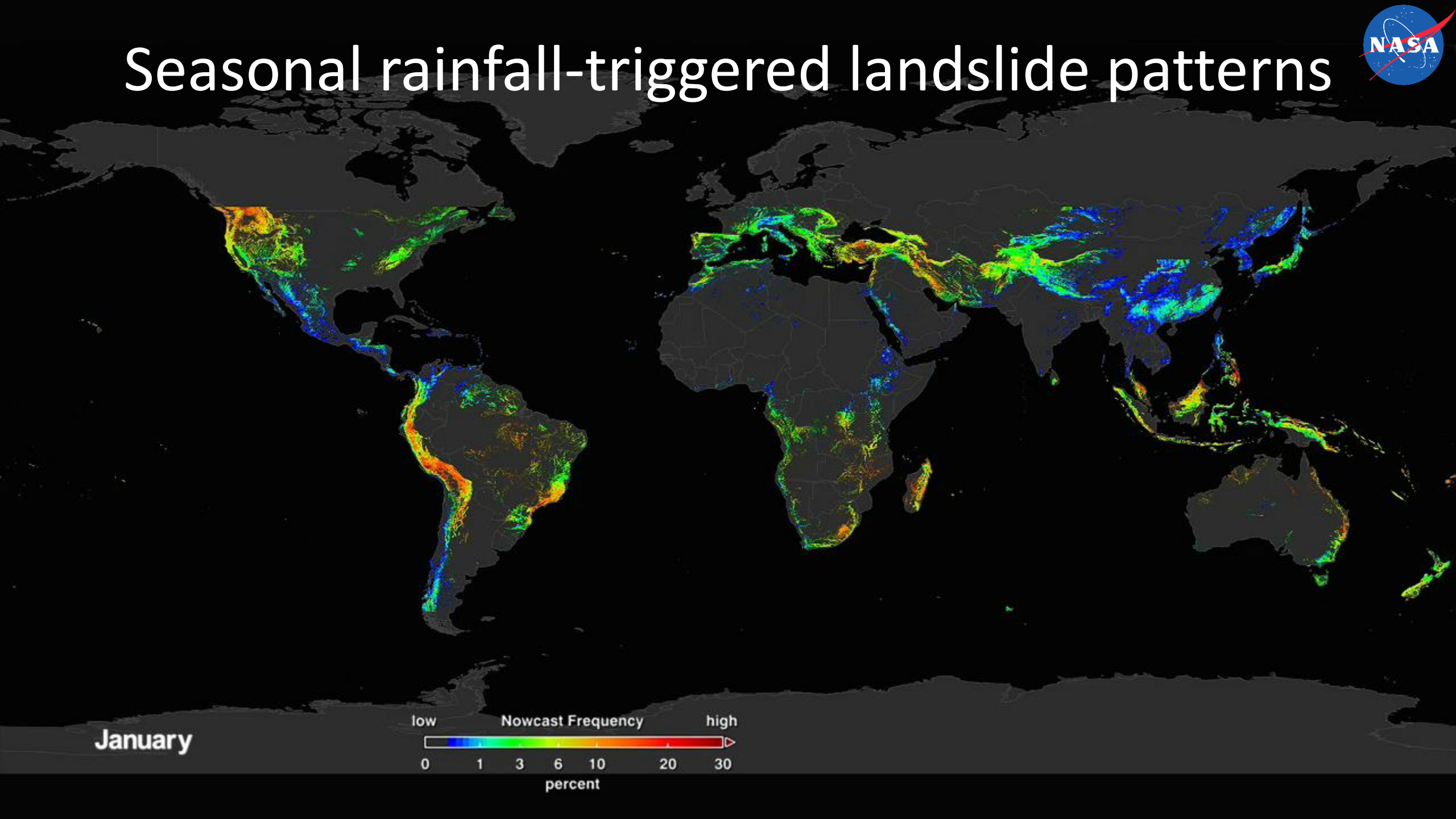


Kirschbaum and Stanley 2018

Near real-time LHASA output

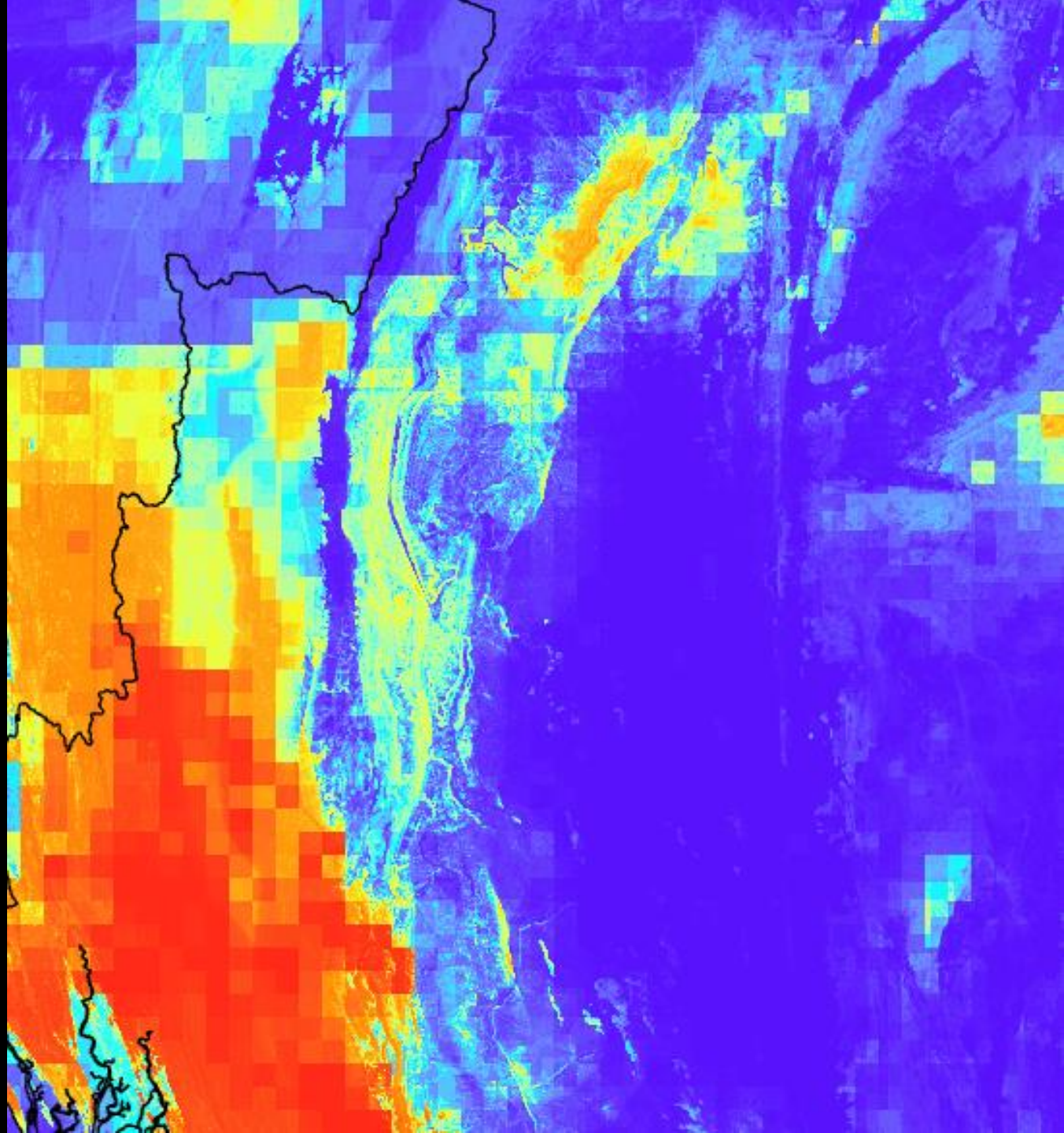


Seasonal rainfall-triggered landslide patterns

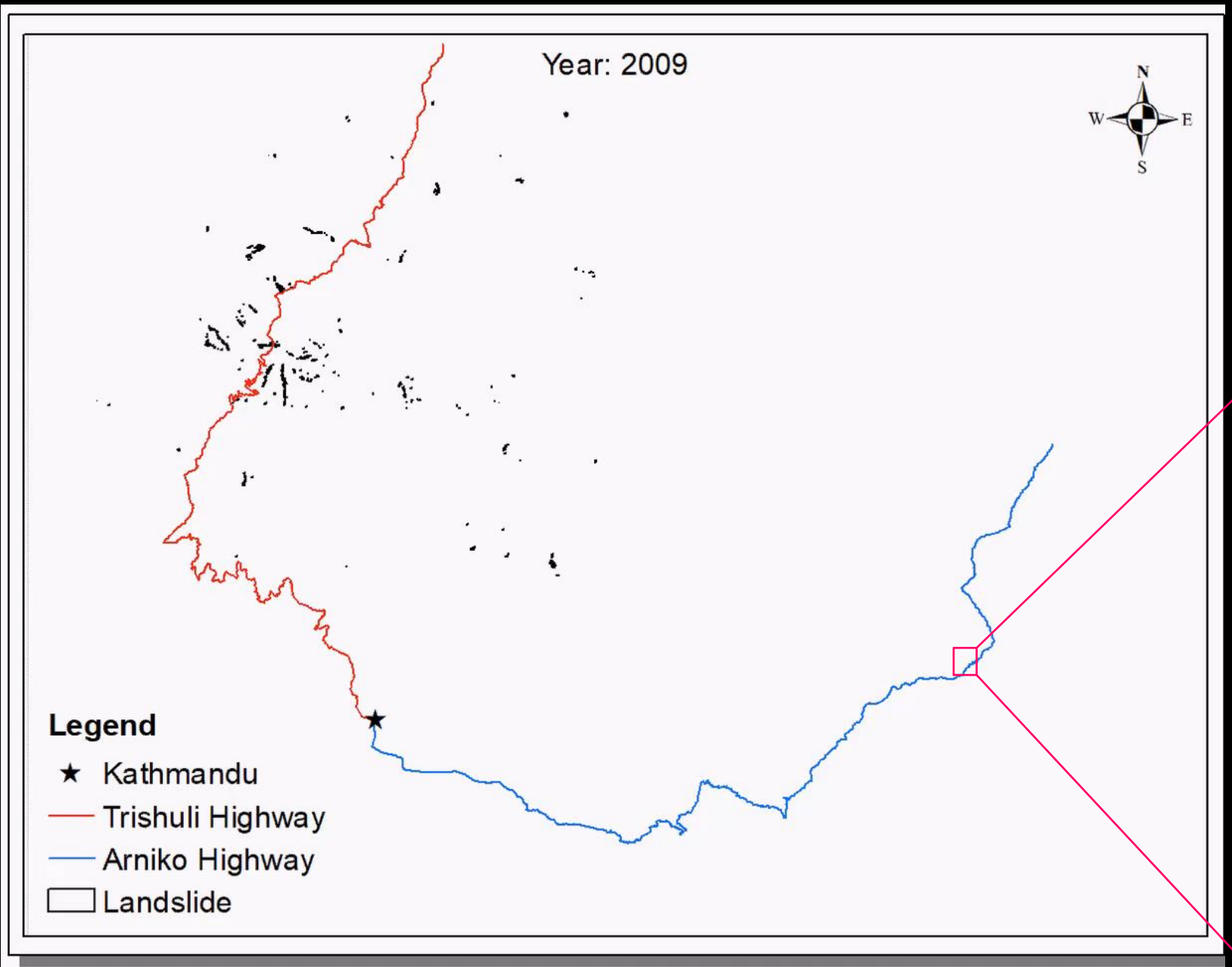


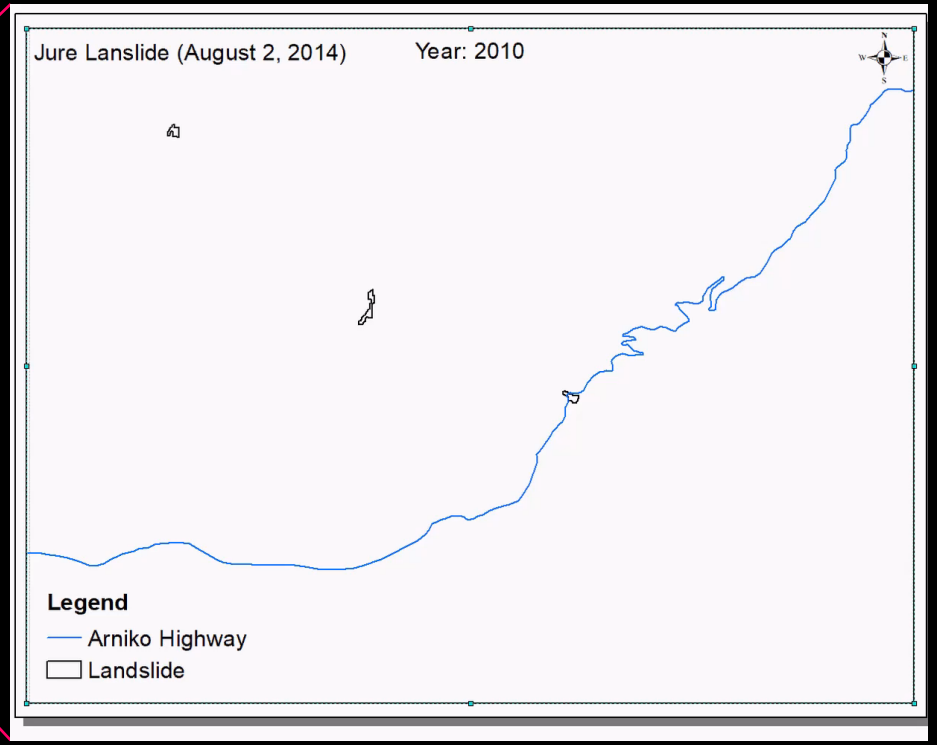
Nowcast Outputs—Global hazard grid

- Daily
  - (but can be produced 48x/day)
- 30-arcsecond
- Global land surface from 60 North to 60 South
  - (optional subsetting)
- Probabilistic (continuous data between 0 and 1)
- 0.5 GB after compression

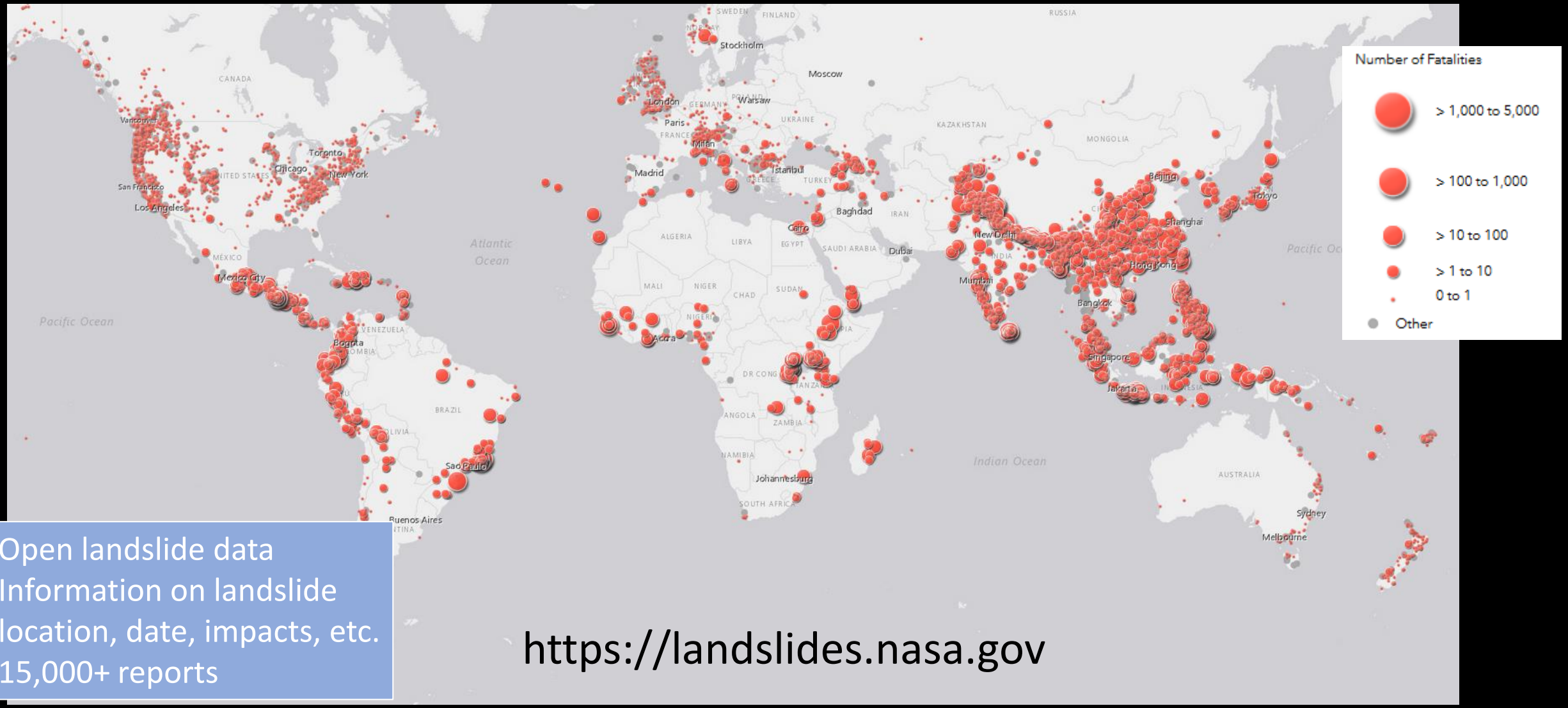


Landslides along Arniko and Pasang Lhamu highway (2009 – 2018)



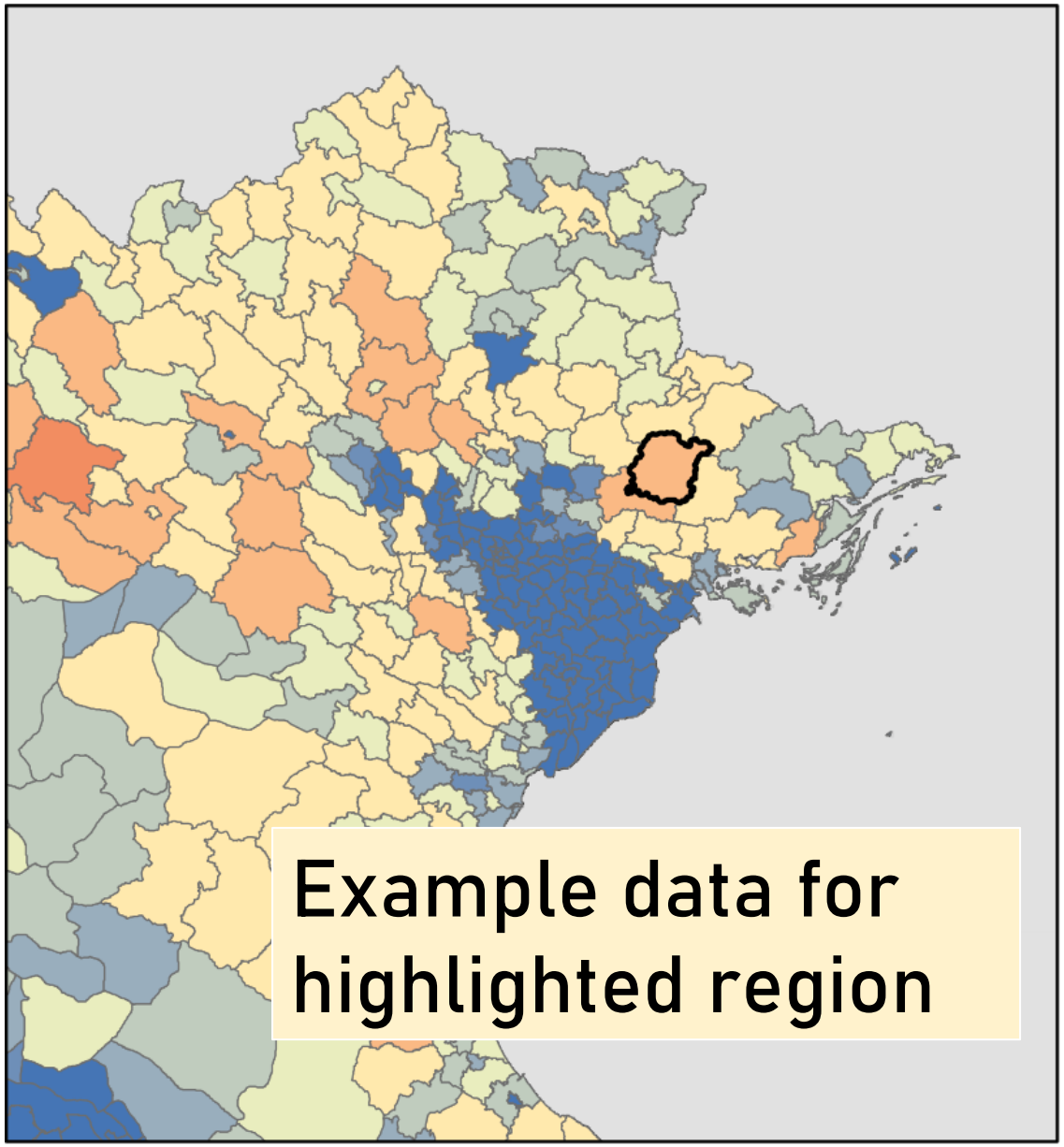


Landslide Reporter: NASA's landslide citizen science project



- Open landslide data
- Information on landslide location, date, impacts, etc.
- 15,000+ reports

https://landslides.nasa.gov



Emberson et al. 2021

ADM-2 Name: Luc Ngan
ADM-1 Name: Bac Giang Province
Country: Vietnam

WorldPop Population Estimate: 217640

LANDSLIDE EXPOSURE

Average Population Exposure:
8.9 Days exposed / year