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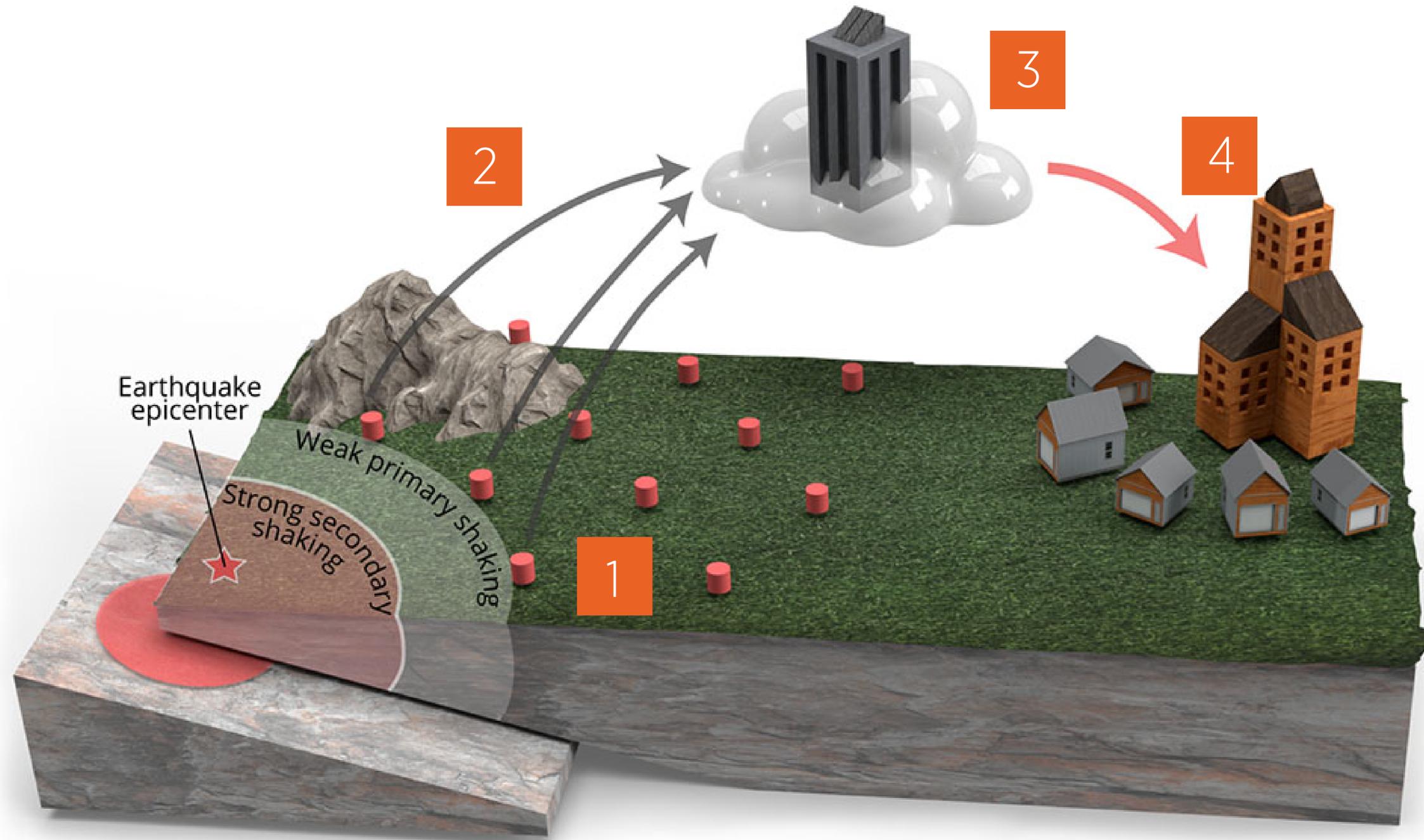
Geoscientists without Borders,  
Society of Exploration Geophysicists

# Development and feasibility testing of a low-cost earthquake early warning system in Nepal

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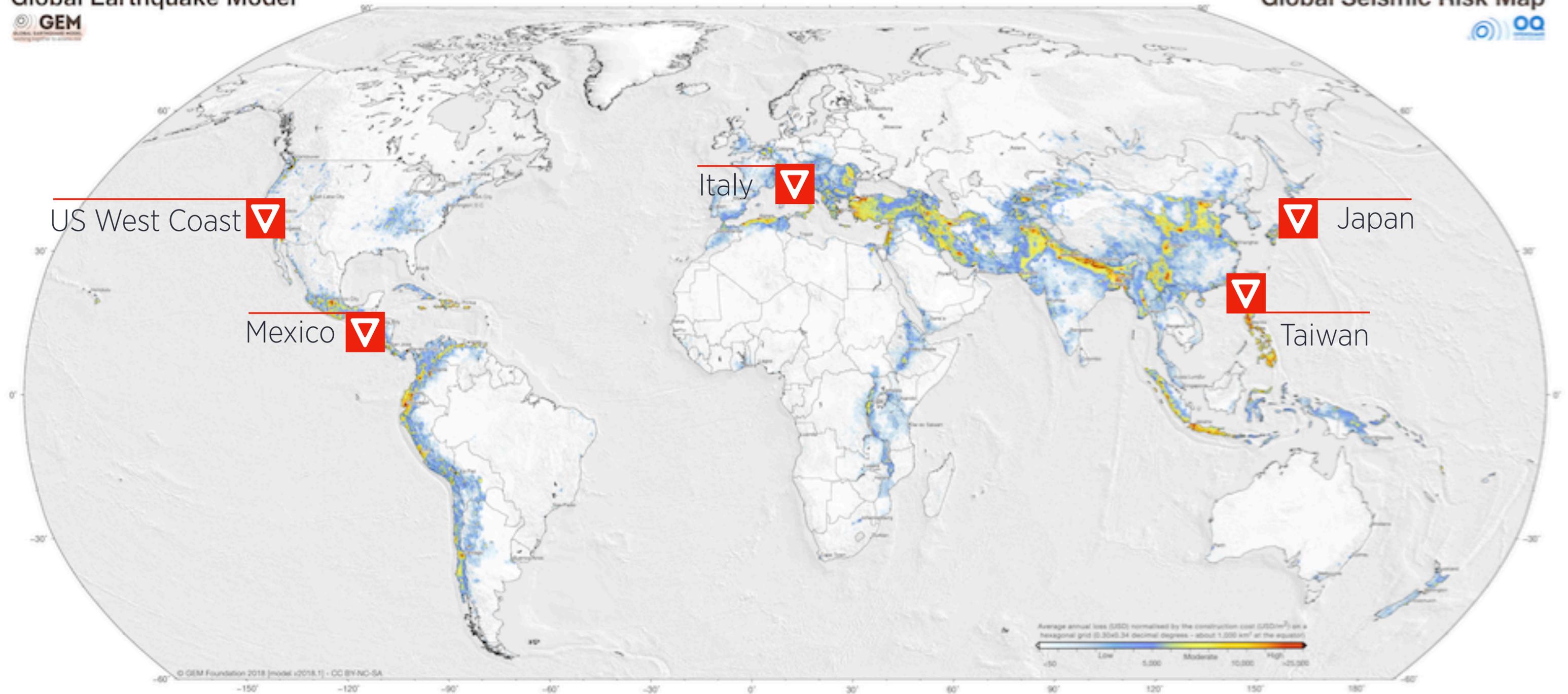
# Earthquake early warning system



# Existing EEW systems

Global Earthquake Model  
**GEM**

Global Seismic Risk Map



# Grillo/OpenEEW

A low-cost, open-source EEW system based on IoT infrastructure.

Low-cost sensor



Cloud-based platform



Smart alert



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Grillo/OpenEEW  
Support:

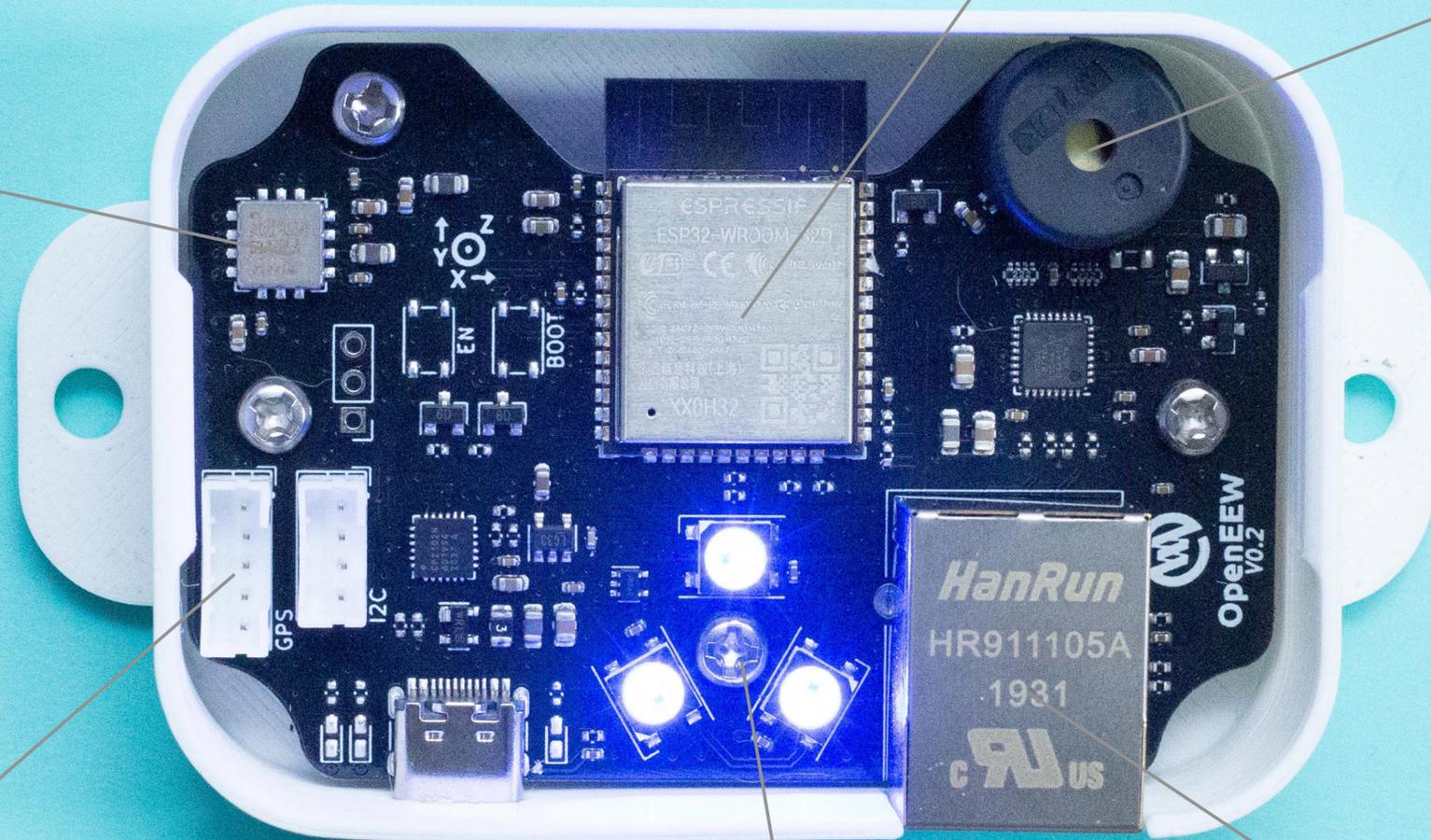


Seismic sensor

MICROCONTROLLER  
ESP32

BUZZER

ACCELEROMETER  
ADXL355



UART  
INTERFACE

NEOPIXEL  
LEDS

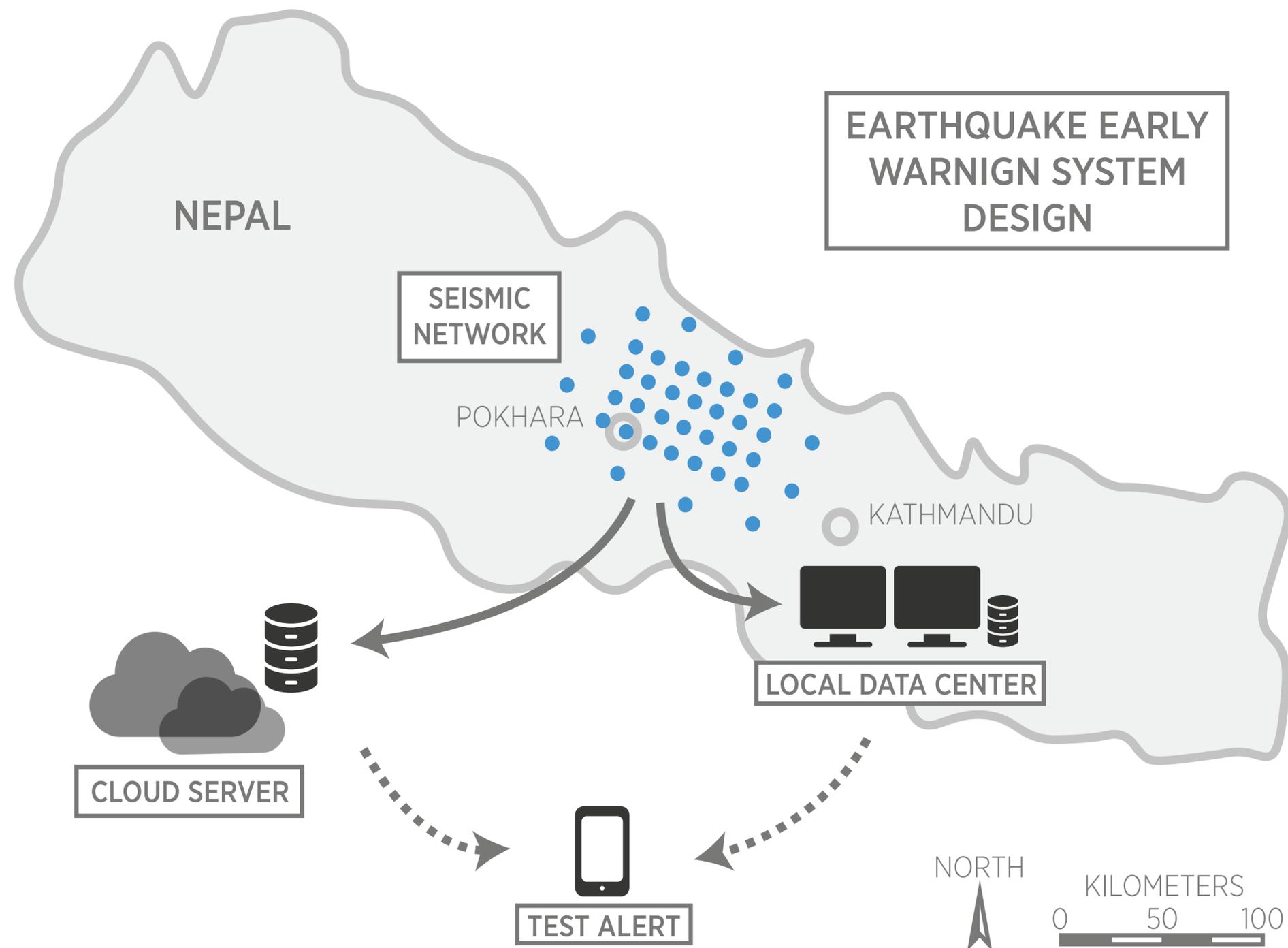
ETHERNET  
PORT

# Cloud platform

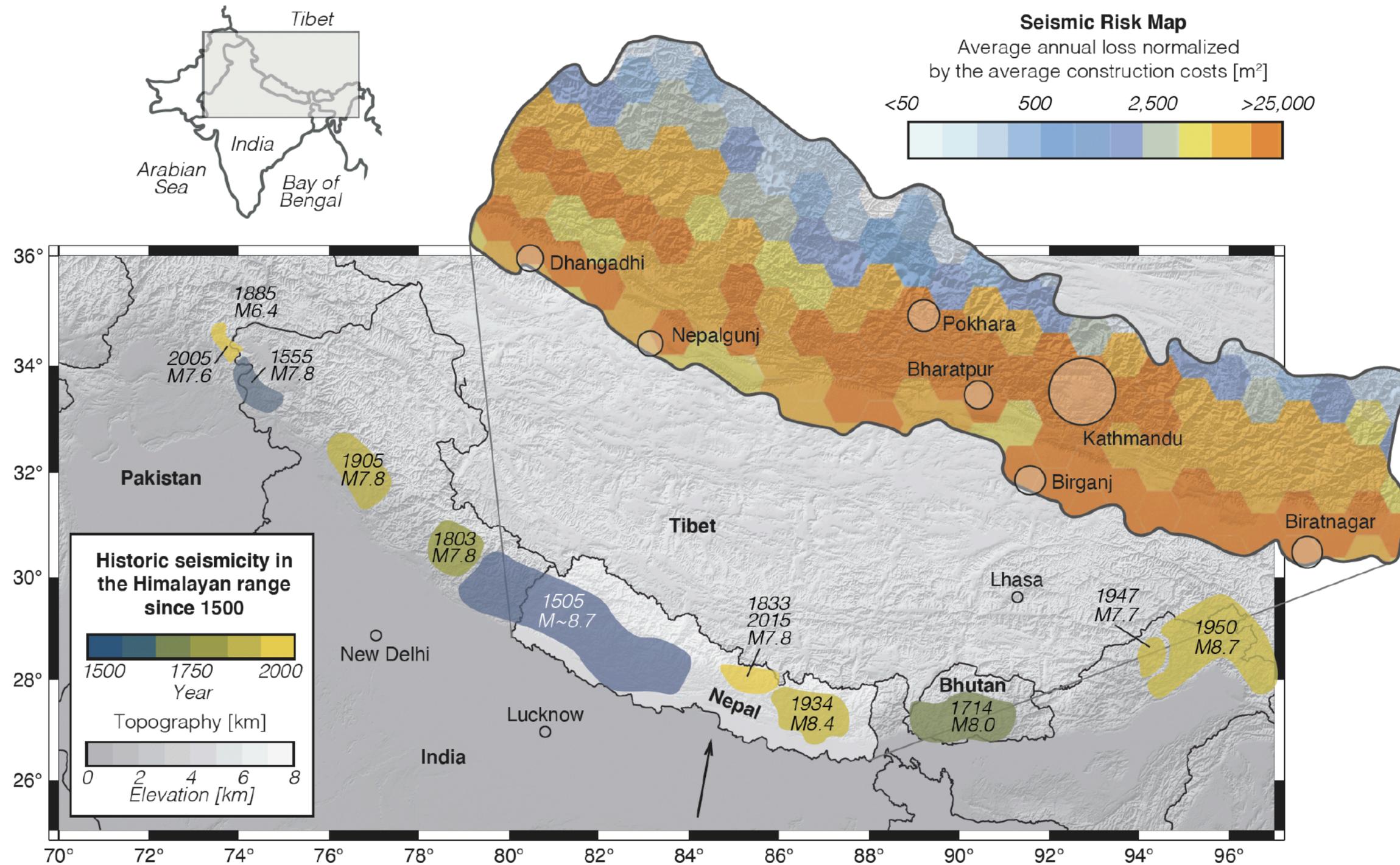
The screenshot shows a web browser window displaying the Grillo dashboard. The browser tabs include 'Task List', 'Inbox (582)', 'Inbox (685)', 'Inbox (14)', 'Inbox (9)', 'grillo.io - C...', 'Grillo - Fig...', 'Grillo - AW...', and 'Grillo Dash...'. The address bar shows 'grillo-dash-board-dev.s3-website-us-east-1.amazonaws.com/network/1/code'. The dashboard header features the Grillo logo, a user profile 'ryan@grillo.io', and a status indicator 'RUNNING OPTIMIZED RESOURCES'. Below the header, there are buttons for 'Launch GrilloLab' and 'console-admin@grillo.io'. The main content area is titled 'Mexico Environment' and shows a table of sensors. The table has columns for sensor ID, region, location, status, and station. The 'BHIM' sensor is highlighted. Below the table is a map of Nepal with sensor locations marked by colored dots. A 'Set Current Center as Default' button is located below the map. A sidebar on the right provides details for the selected 'Grillo Sensor', including its location 'Bhimad, Western Development Region, NP', network 'NP', station 'BHIM', description 'Station in Bhimad', and status 'Connected Mar 23, 2022 at 12:05:32 PM GMT+1'.

ASTM	NP	Pokhara Sub Metro, Western Development Region, NP	1 month ago	Station in Astam
BENI	NP	Arthunge, Western Development Region, NP	9 hours ago	Station in Beni
<b>BHIM</b>	NP	<b>Bhimad, Western Development Region, NP</b>	<b>1 day ago</b>	<b>Station in Bhimad</b>
BLGN	NP	Baglung, Western Development Region, NP	9 hours ago	Station in Baglung
BNDP	NP	Bandipur, Western Development Region, NP	10 hours ago	Bandipur station
BNGT	NP	BeniGhat, Central Development Region, NP	10 hours ago	Station in Benighat
BSSR	NP	Besishahar, Western Development Region, NP	2 days ago	Station in Besisahar
DAML	NP	Byas, Western Development Region, NP	2 days ago	Station in Damaule
DDNK	NP	Leknath, Western Development Region, NP	1 day ago	Station at Shri's parents
EMPTY	--	Not Available	Not Available	
EMPTY	--	Not Available	Not Available	
EMPTY	--	Not Available	Not Available	
EMPTY	--	Not Available	2 months ago	LSE
GR002	HT	Pötoprens, Département de l'Ouest, HT	2 days ago	Digicel Tower PaP
GR01	--	Not Available	Not Available	Haiti

# System testing in Nepal

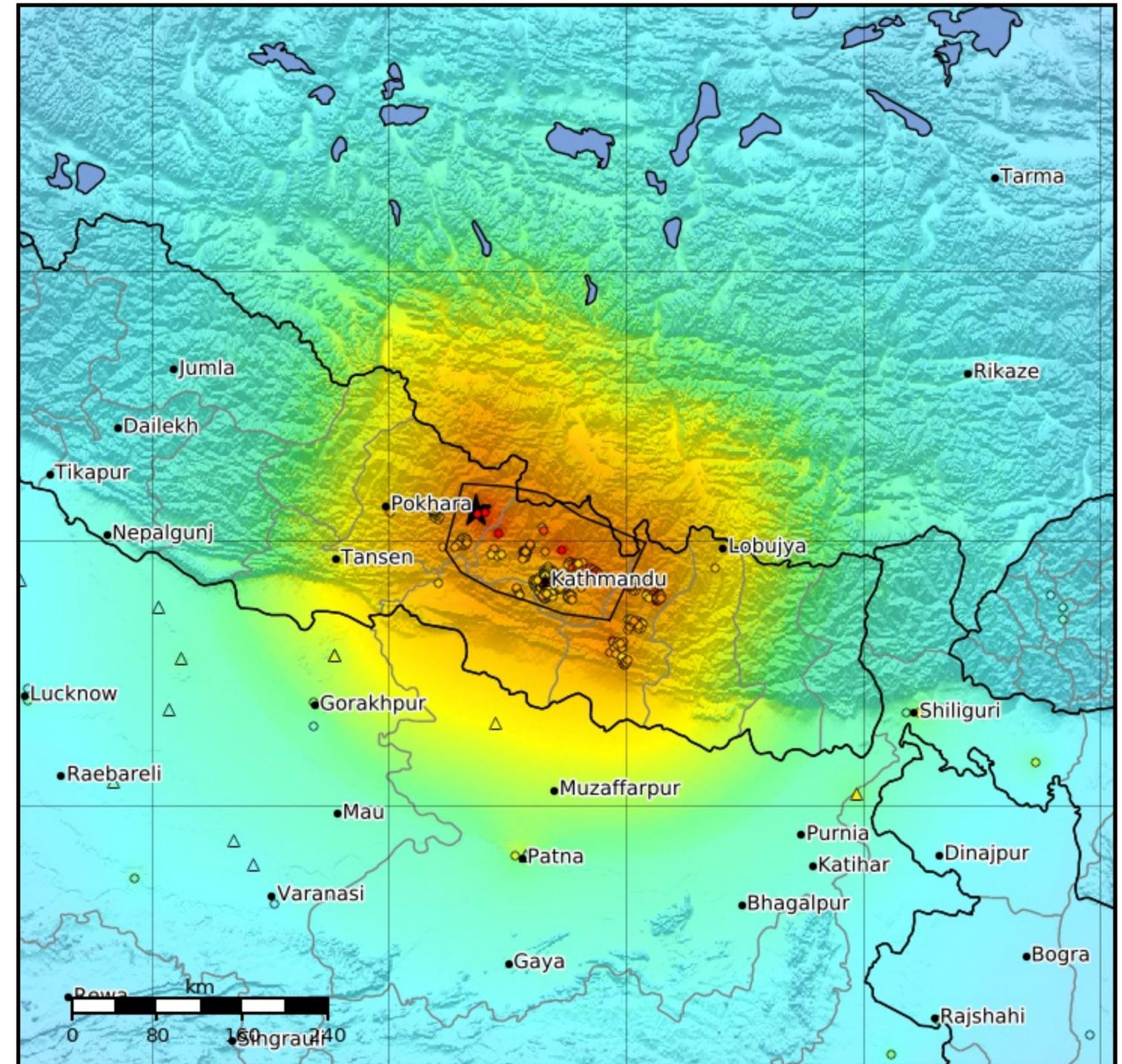


# Seismic hazard and risk in Nepal

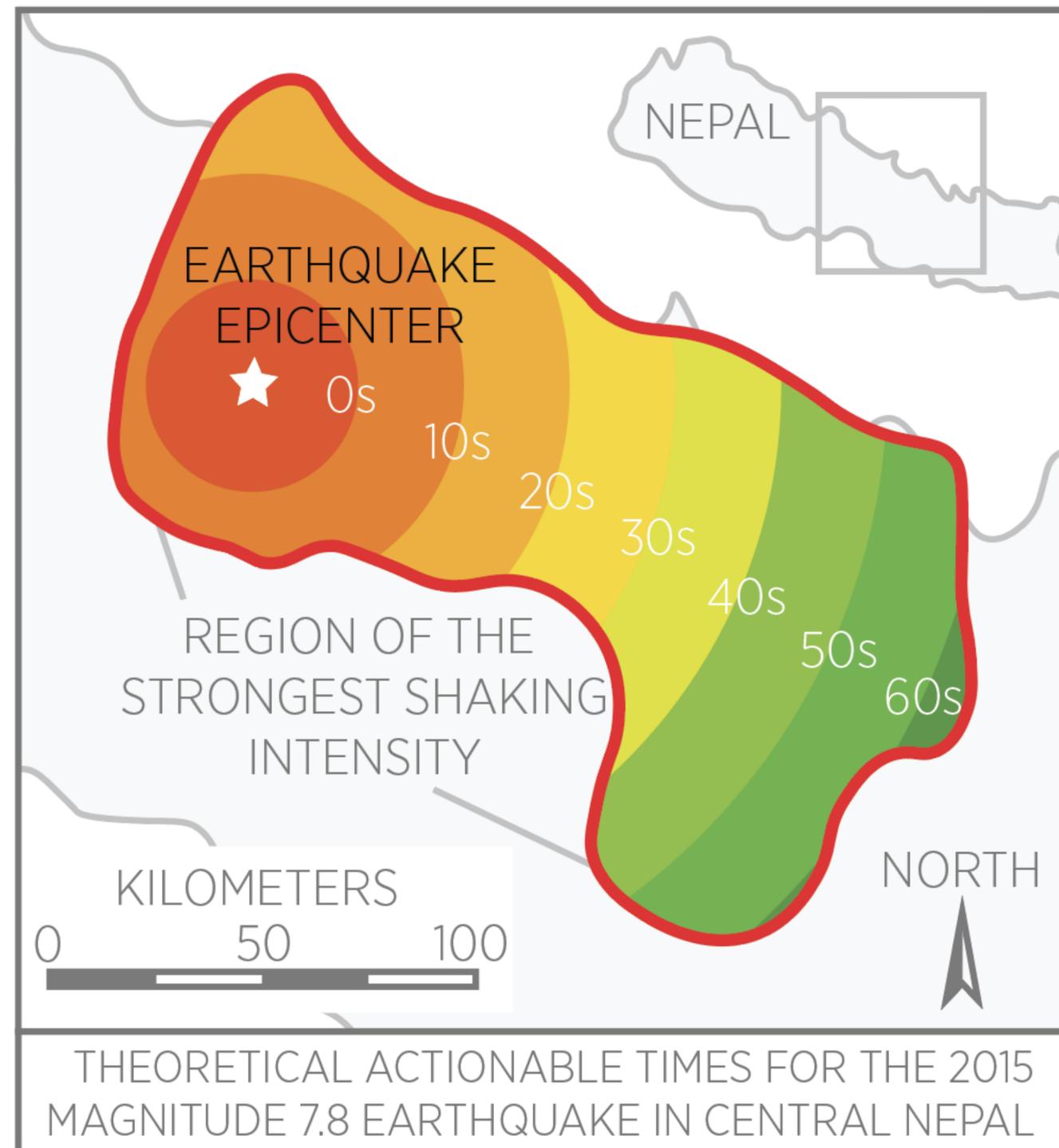


# Gorkha earthquake - April 25, 2015, M 7.8

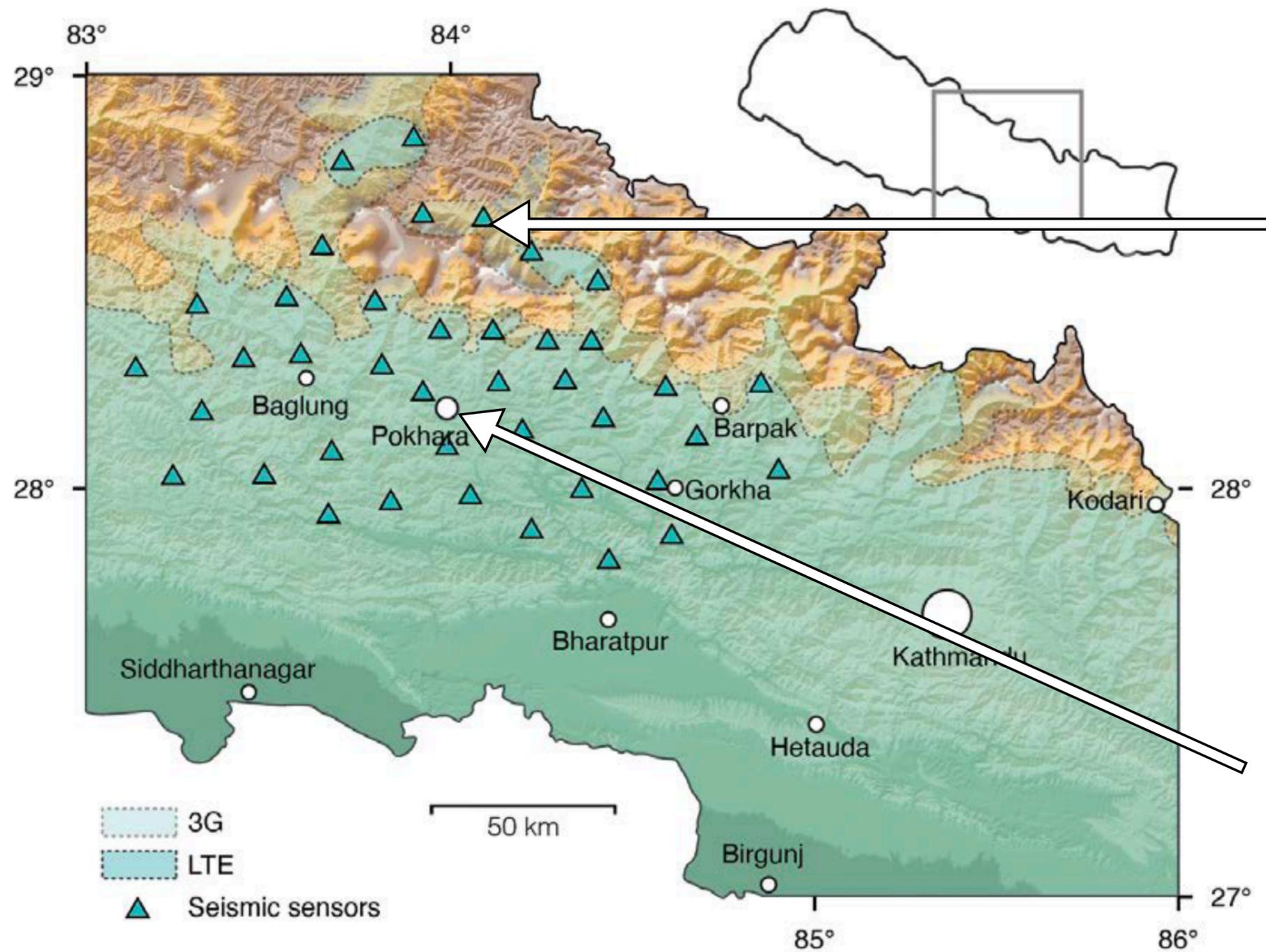
- ~9,000 fatalities
- Damage: 10\$ billion



# Potential actionable times provided by EEW system



# Nepal EEW experiment 2021/2023



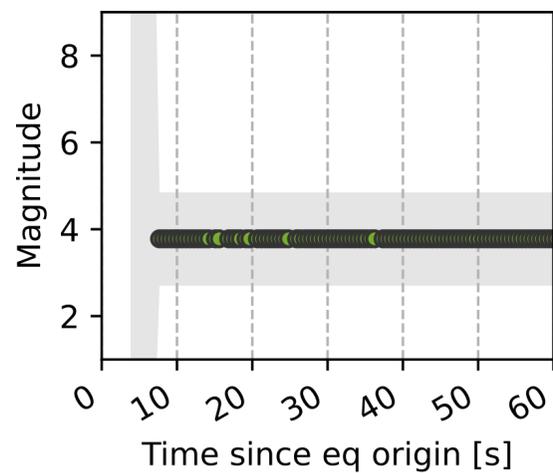
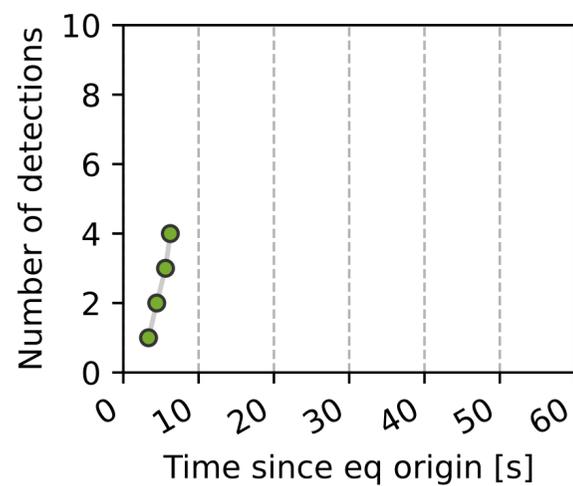
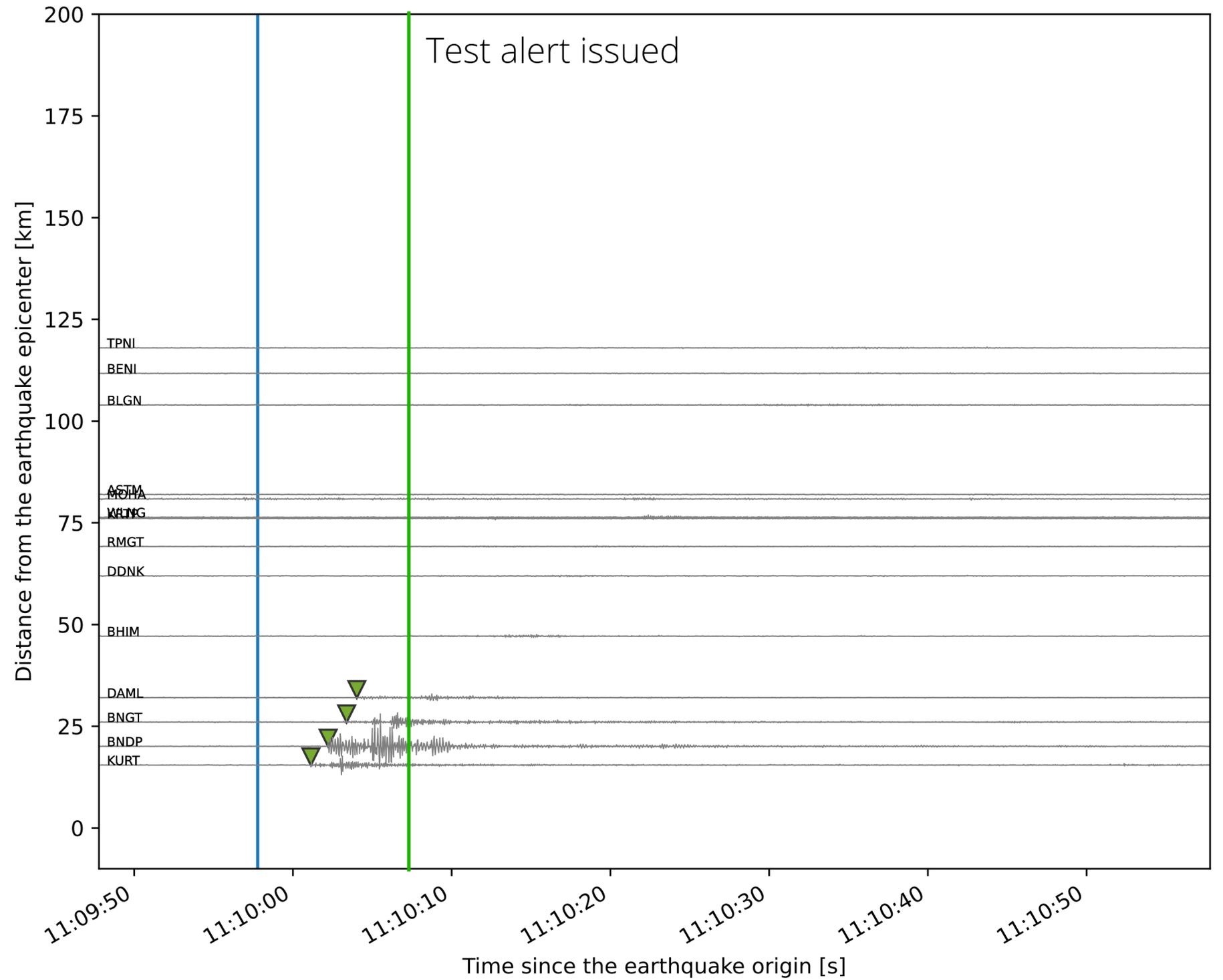
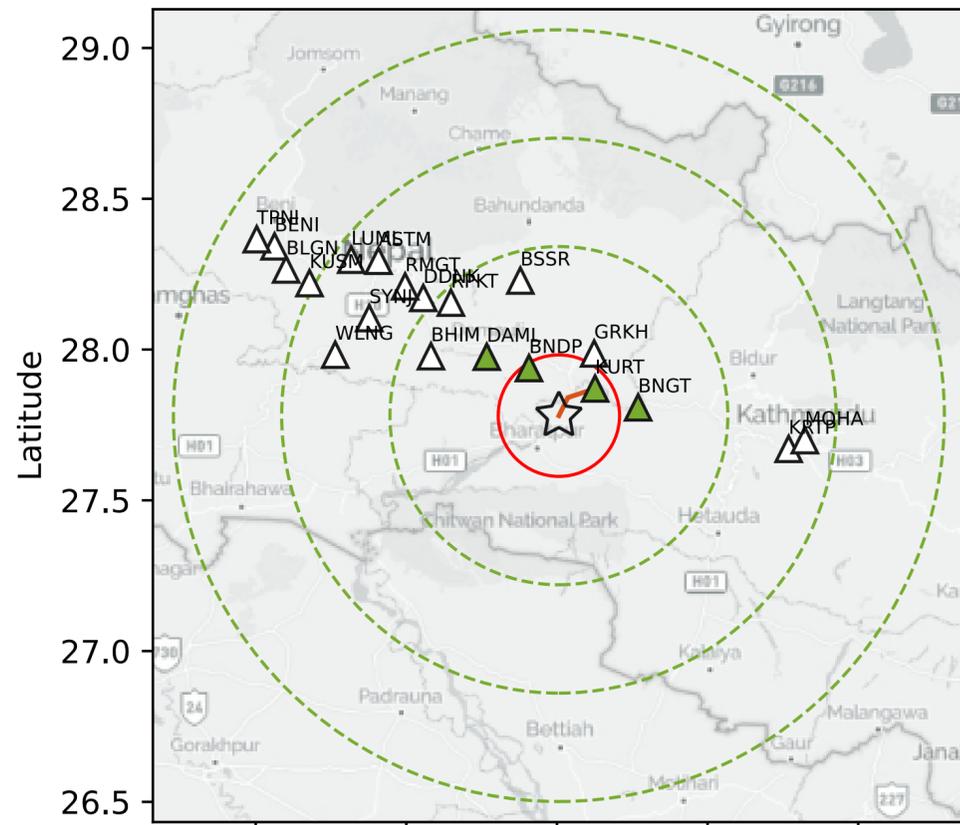
# November 2021 station deployment



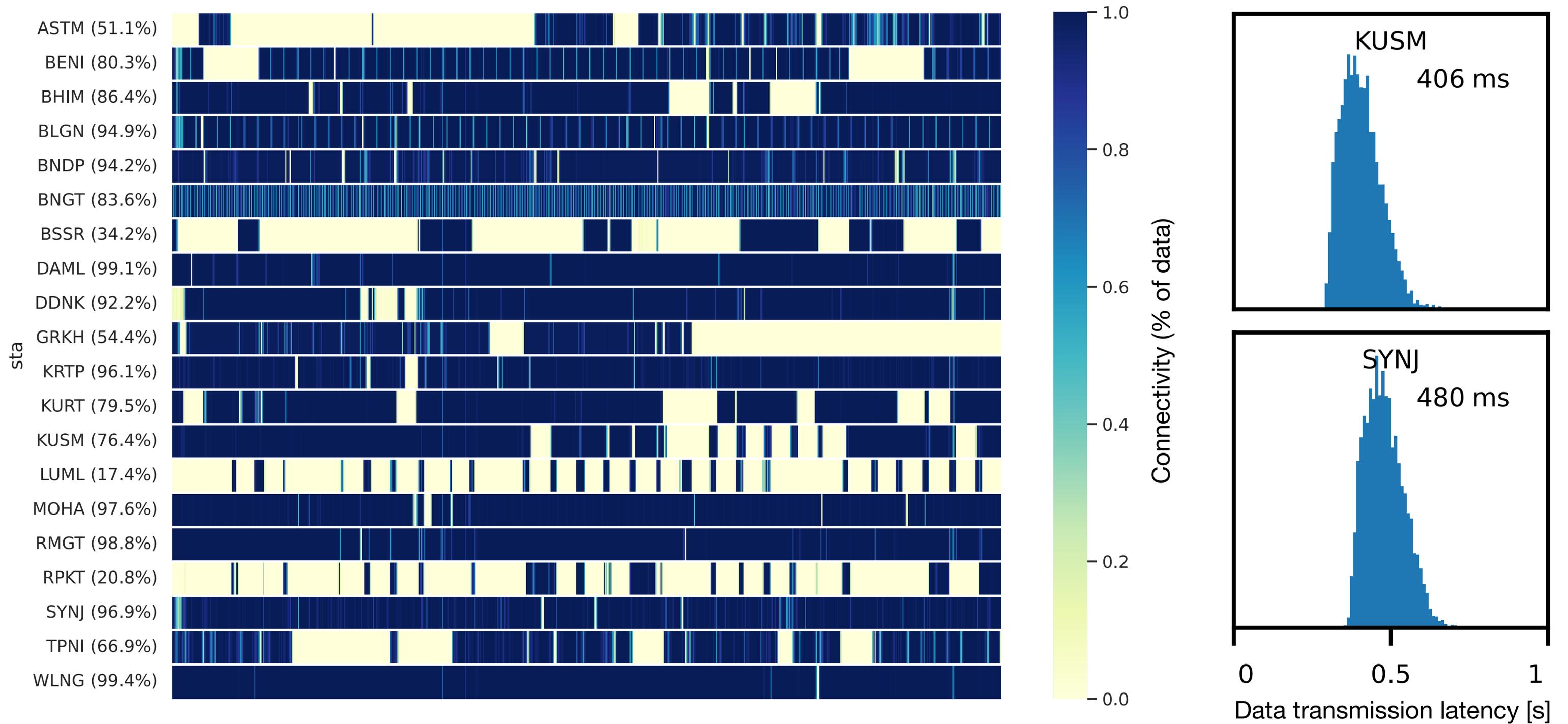
# November 2021 station deployment



# Real-time earthquake determinations



# Station connectivity and data transmission latency



# Thank you for your attention!

## Acknowledgements:

- Dr. John Nabelek (Oregon State University)
- Dr. Soma Nath Sapkota
- Dr. Anil Pokhrel (National Disaster Risk Reduction & Management Authority)



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# Rapid earthquake characterization

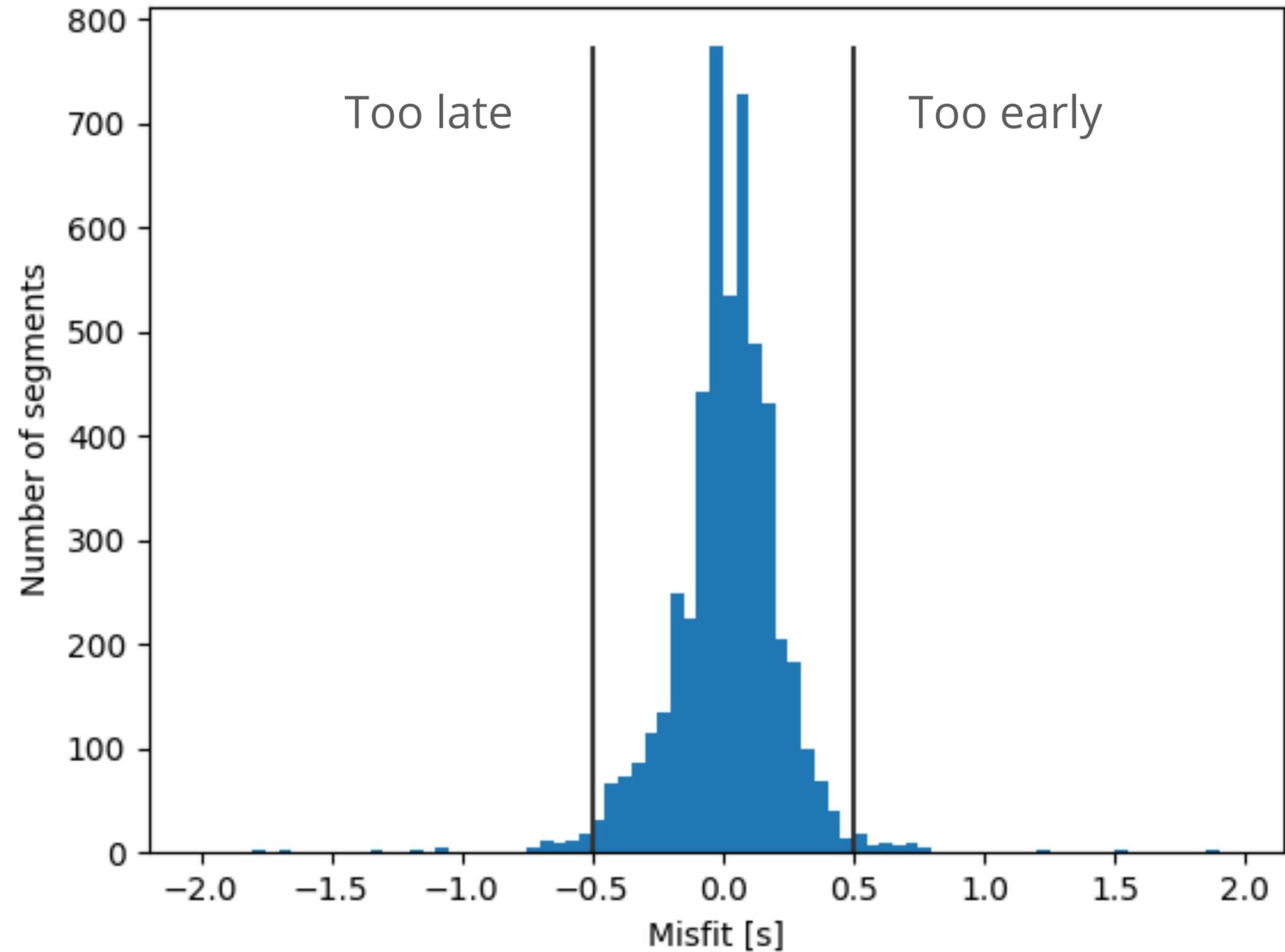
## 1. Detection: STA/LTA, Neural-network picking

```
MODEL PREDICTION EVALUATION
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```

	P	noise
Tag	4987	185
No tag	273	84865

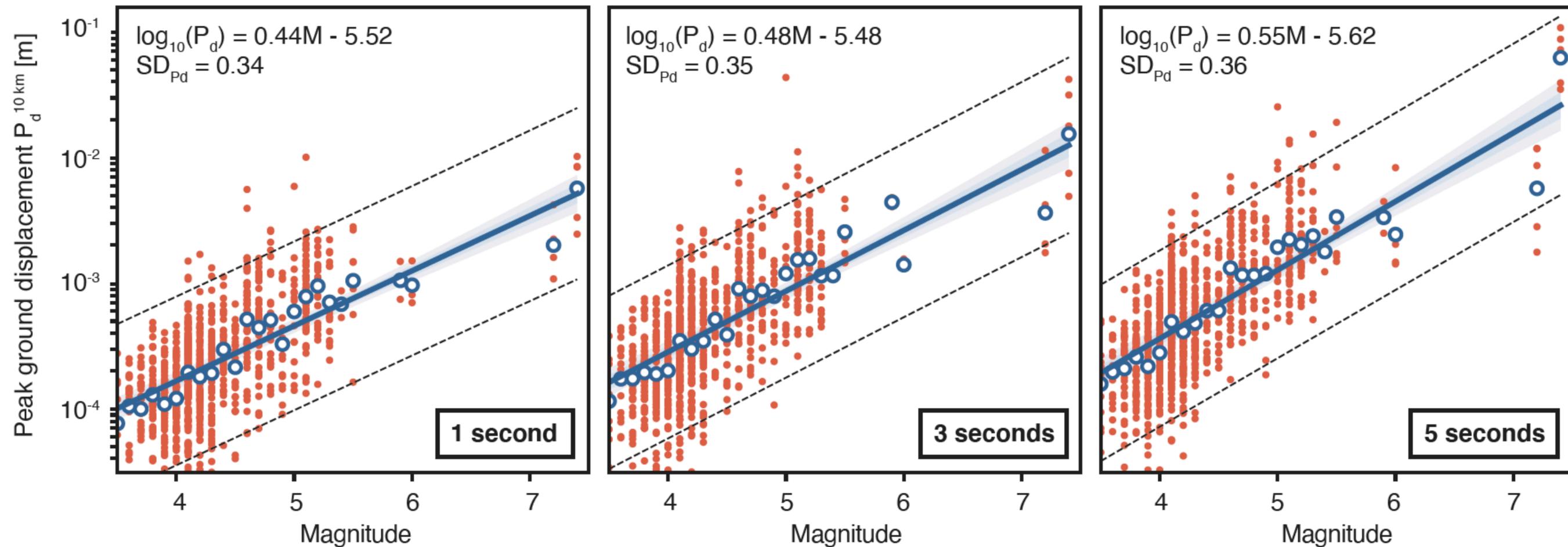
```
Precision: 0.96
Recall: 0.95
Hit misfit: mean 0.03, std 0.30

////////////////////////////////////
// F1 score: 0.96 //
////////////////////////////////////
```



# Rapid earthquake characterization

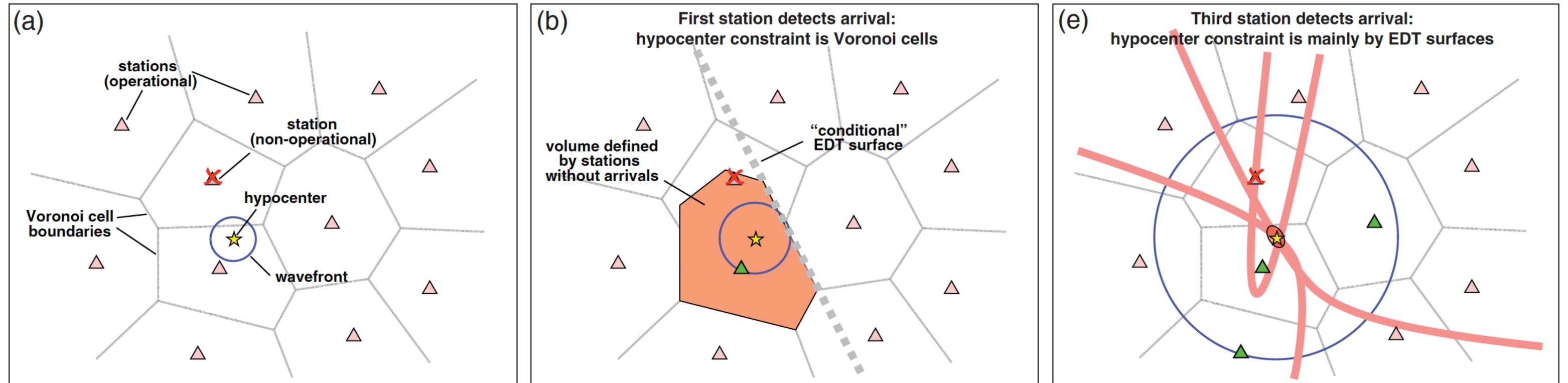
1. Detection: STA/LTA, Neural-network picking
2. Magnitude: Bayesian estimation from peak ground displacement of initial portion of P-wave



Following Lancieri, M., and A. Zollo (2008), A Bayesian approach to the real-time estimation of magnitude from the early P and S wave displacement peaks, *J. Geophys. Res.*, 113, B12302, doi:10.1029/2007JB005386.

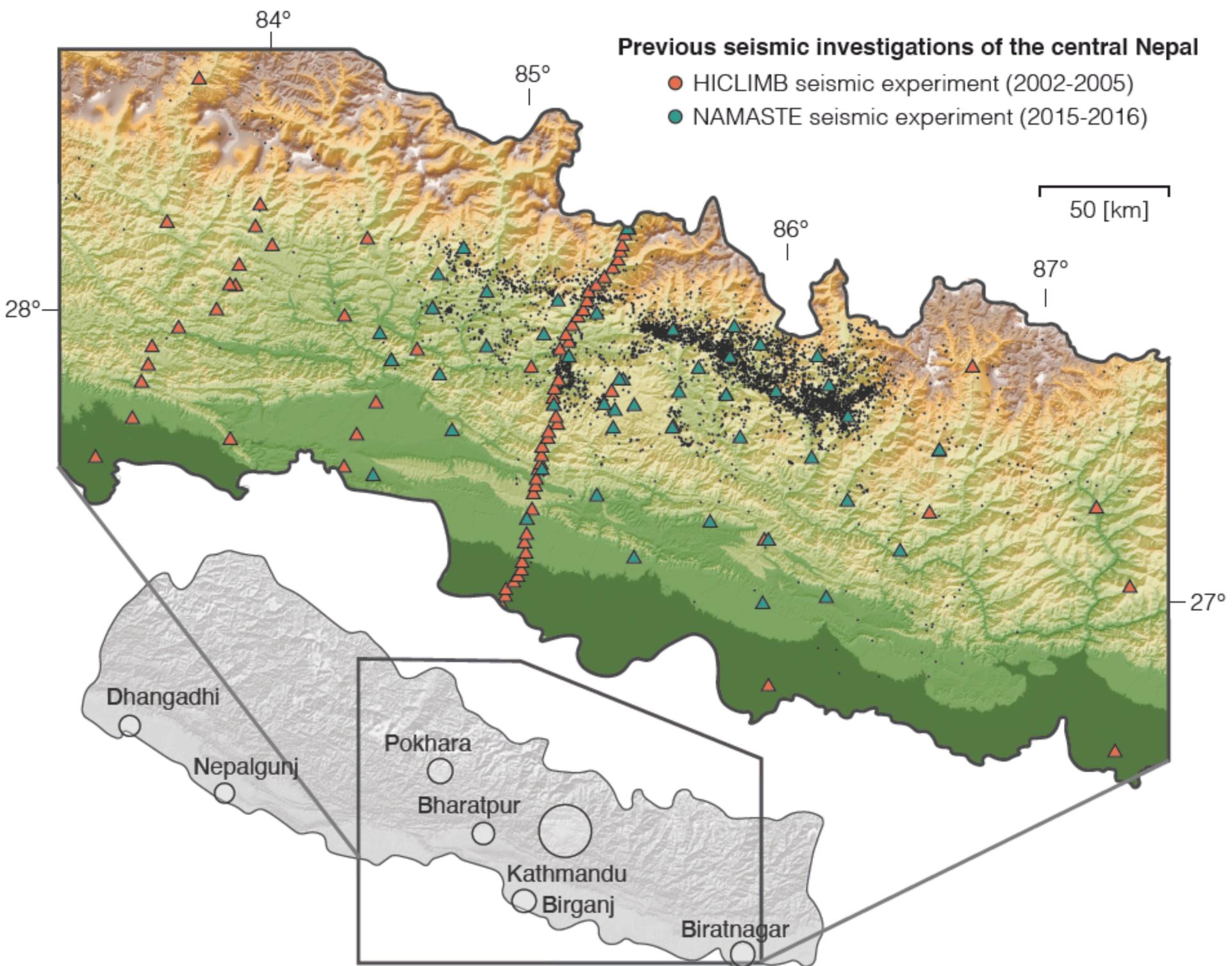
# Rapid earthquake characterization

1. Detection: STA/LTA, Neural-network picking
2. Magnitude: Bayesian estimation from peak ground displacement of initial portion of P-wave
3. Location: Bayesian estimation from P-wave arrivals

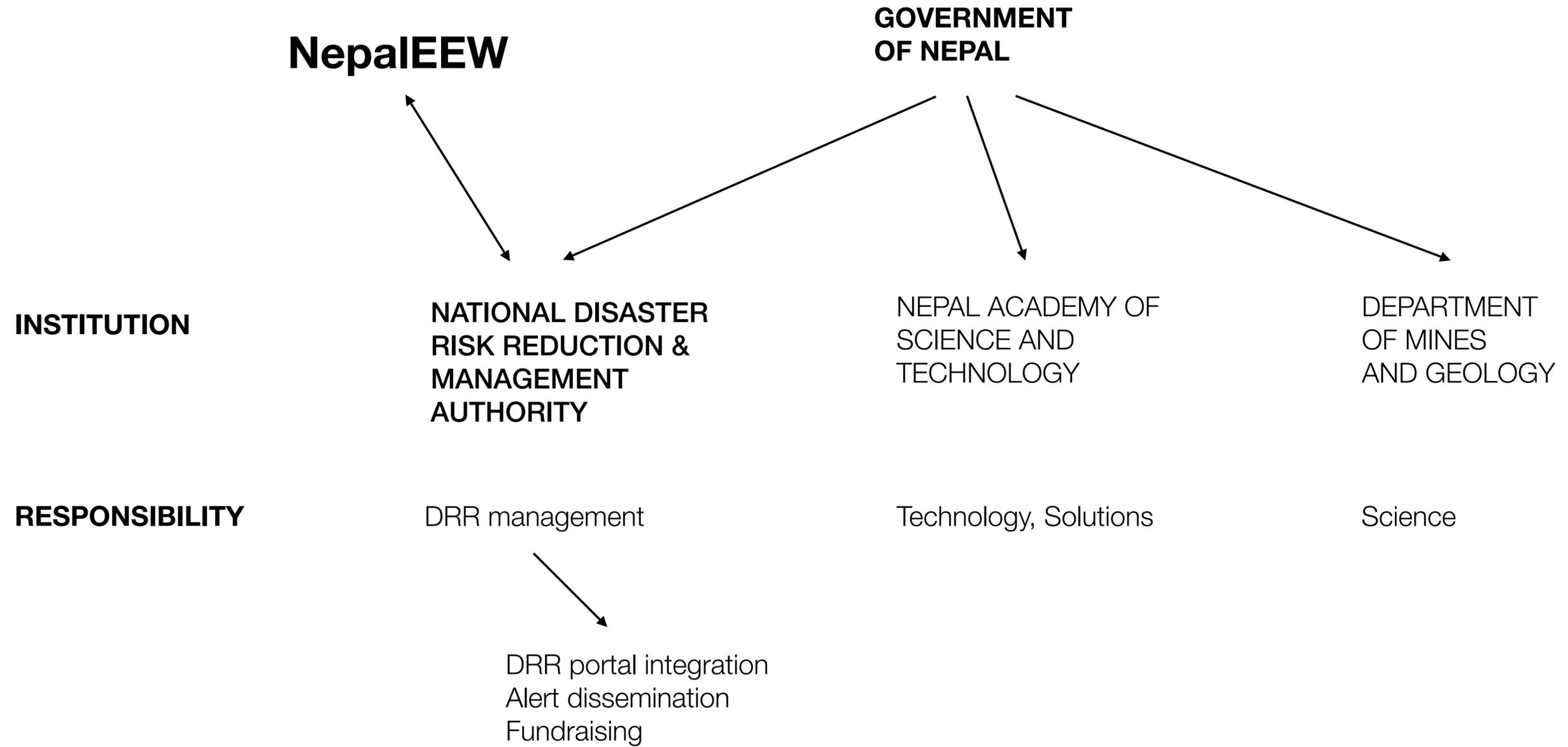


Following Satriano, C., Lomax, A. and Zollo, A., 2008. Real-time evolutionary earthquake location for seismic early warning. Bulletin of the Seismological Society of America, 98(3), pp.1482-1494.

# NAMASTE experiment 2015/2016



# Collaborations



# System latency

