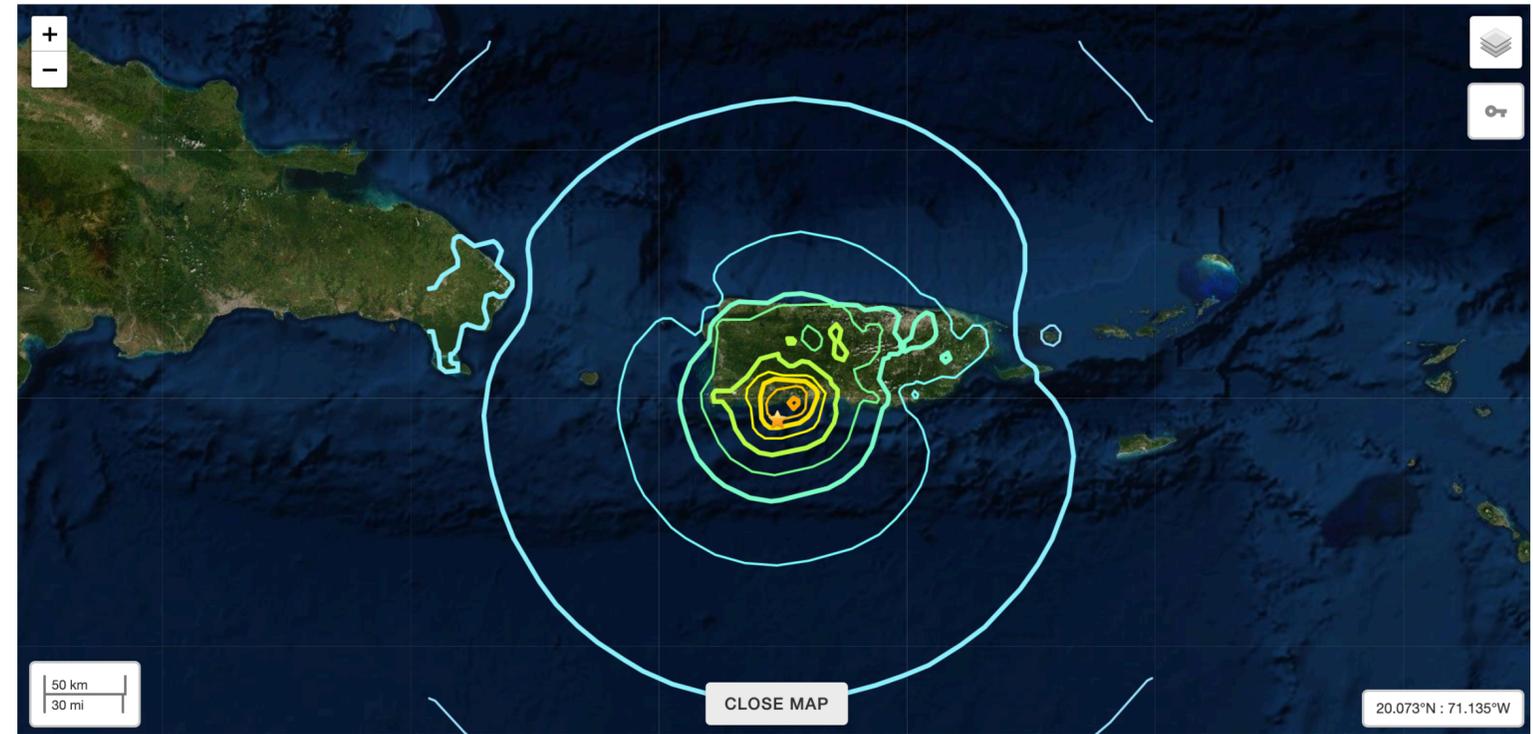


# The 2020 SW Puerto Rico Earthquake and Aftershocks

Nicholas van der Elst  
Andrew Michael  
Jeanne Hardebeck  
Sara McBride

# Overview

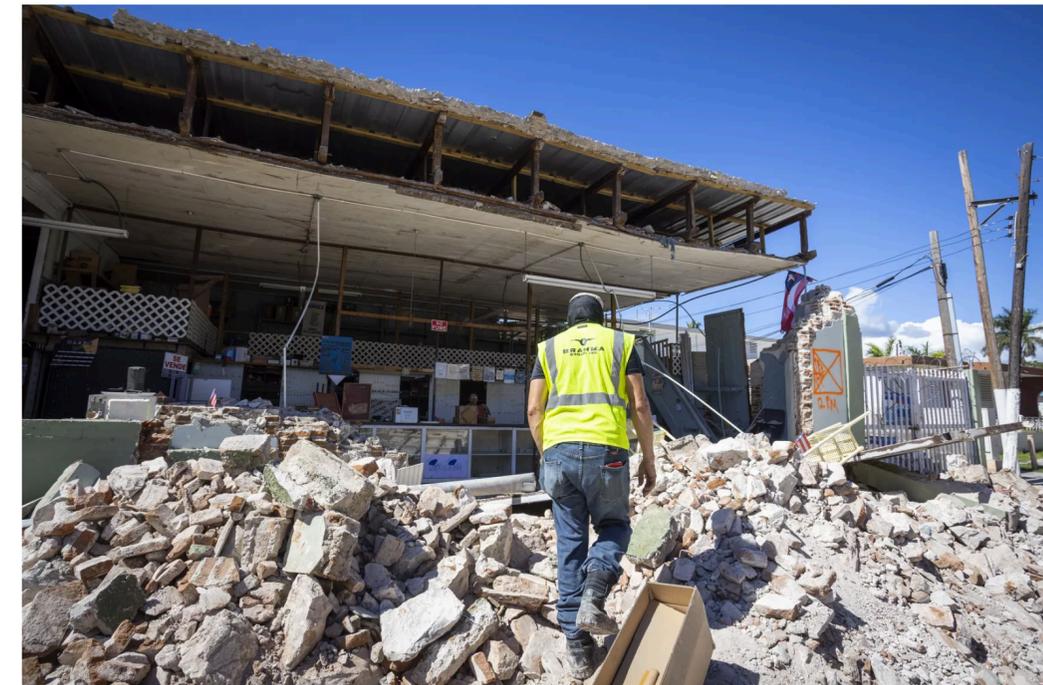
- Jan 7: a magnitude 6.4 earthquake struck off SW Puerto Rico at 4:24 am local time.
- At least one direct fatality (plus 3 heart attacks).
- Economic damage likely in the billions USD.
- Thousands still in tent communities as of February 27 experiencing daily aftershocks.



Ricardo Arduengo/AFP/Getty Images

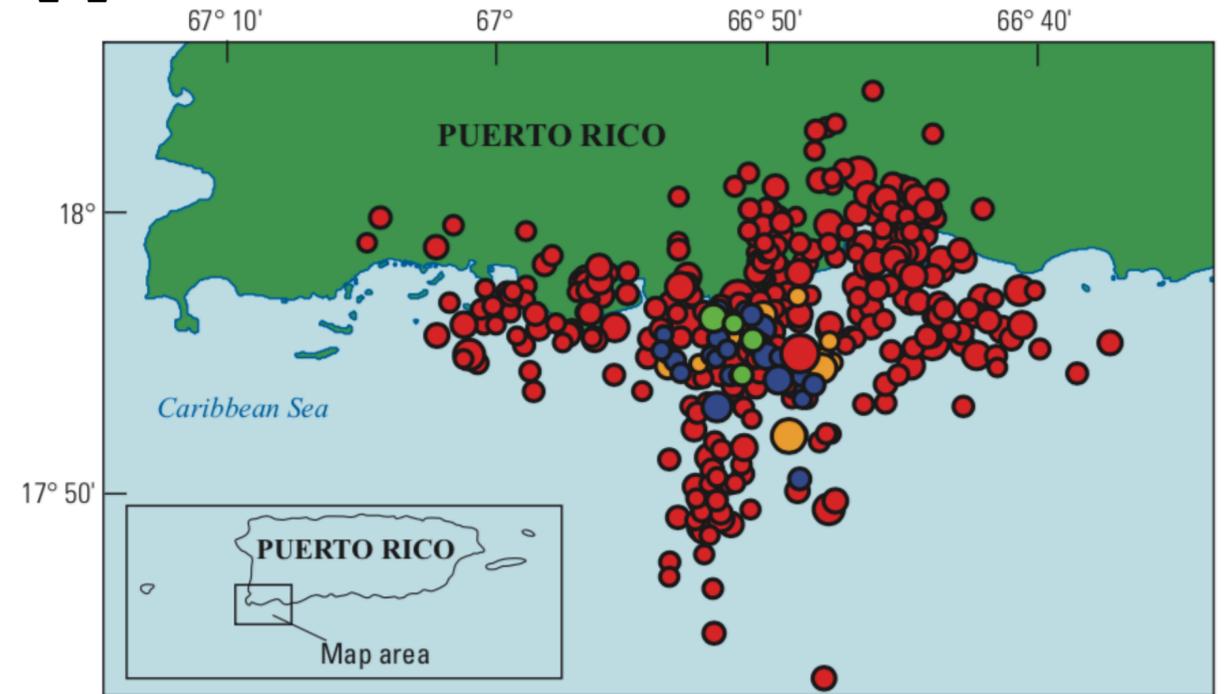
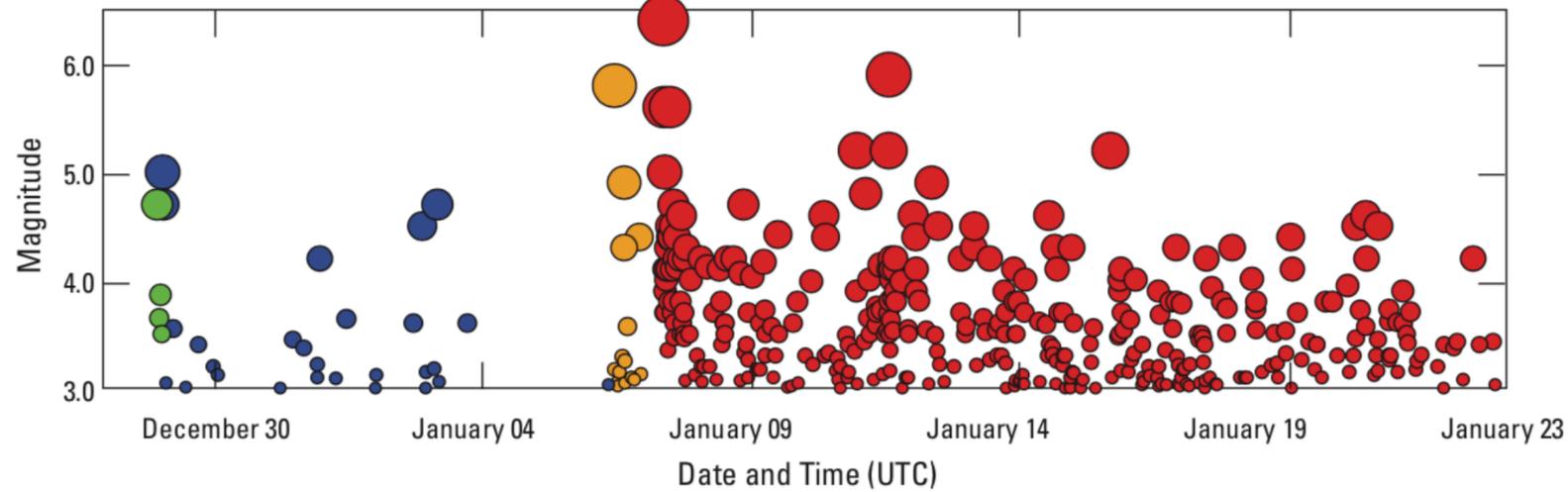


Ricardo Arduengo/AFP/Getty Images



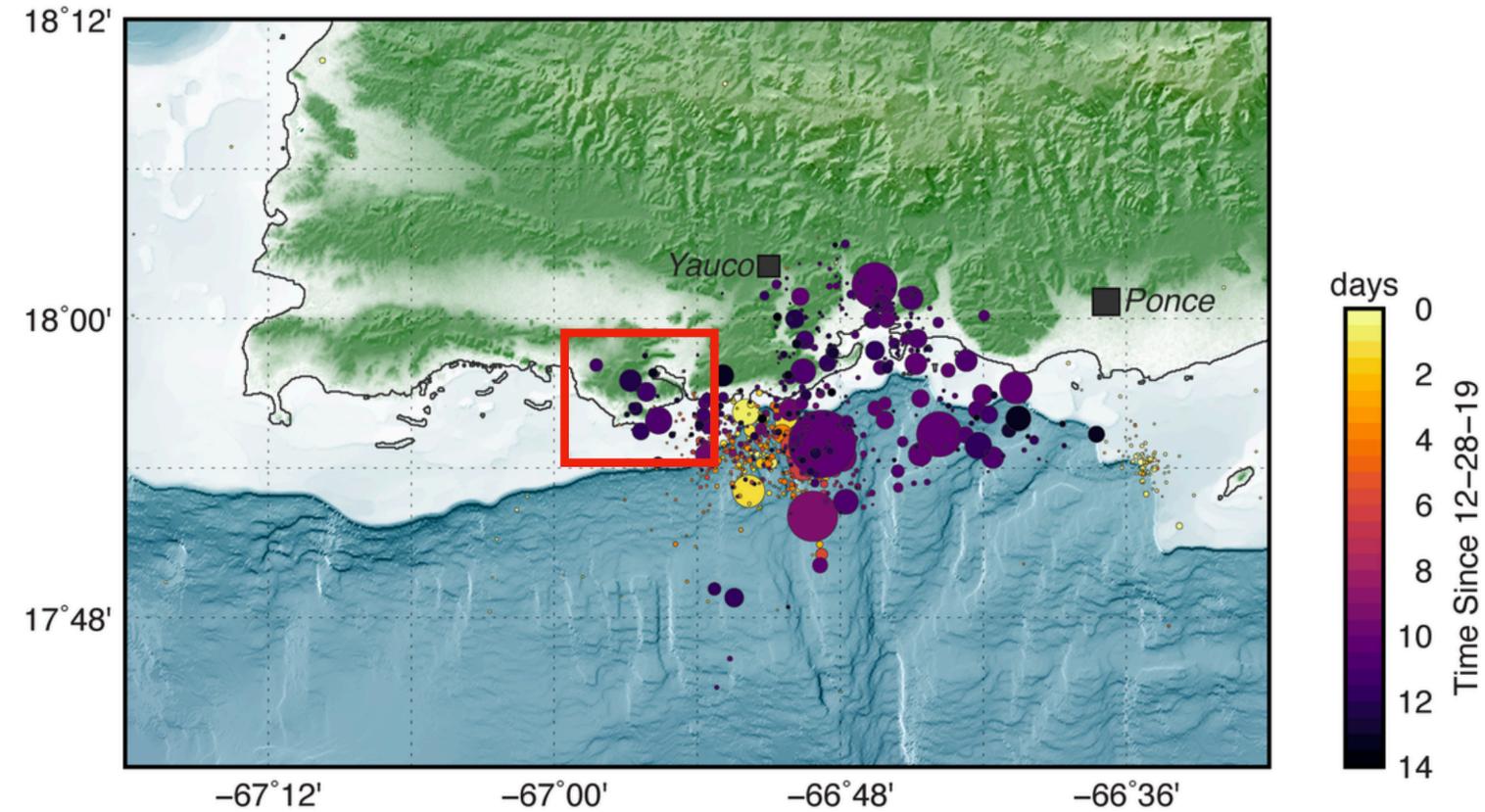
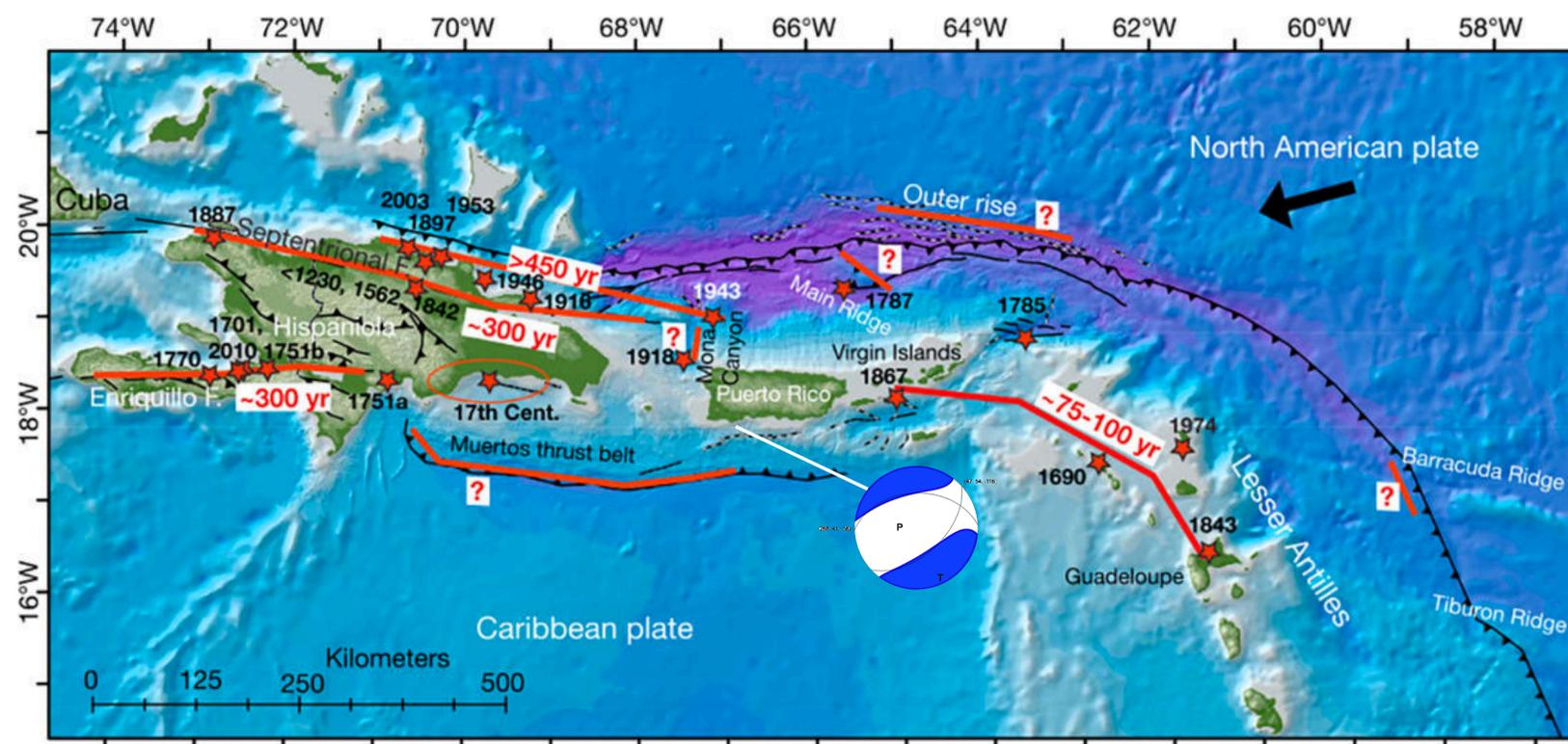
Alejandro Granadillo/Anadolu Agency/Getty Images

# Overview

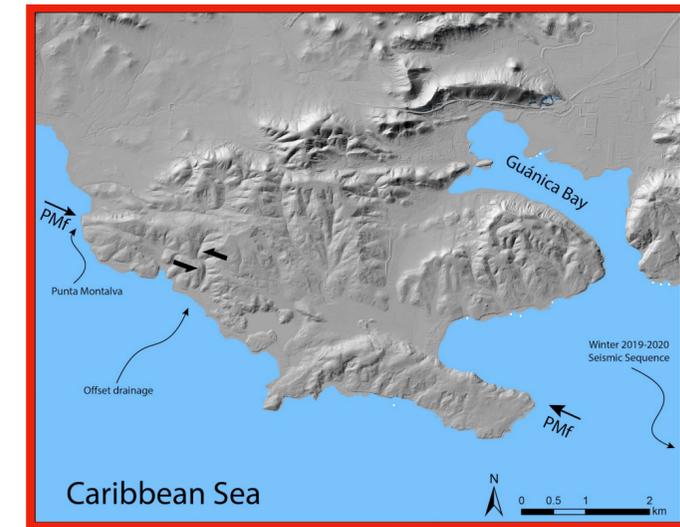
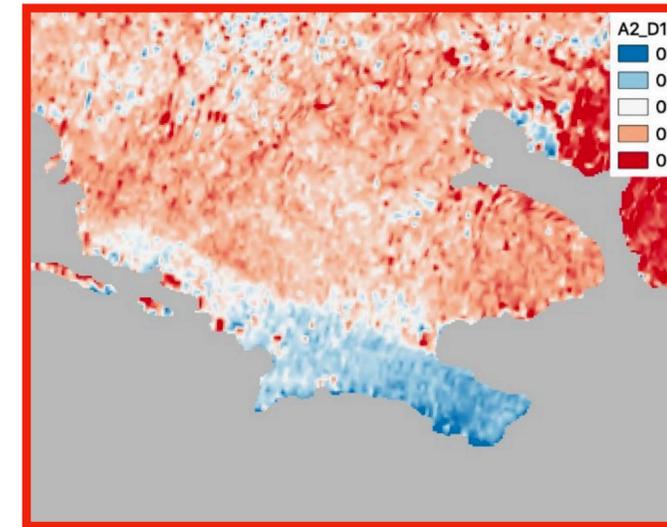


Date (UTC)	Time (UTC)	Magnitude	Latitude	Longitude	Depth <sup>2</sup> , in kilometers
Dec. 29, 2019	01:06:00	5.0	17.885° N	66.864° W	6.0
Jan. 6, 2020	10:32:18	5.8	17.867° N	66.819° W	6.0
Jan. 7, 2020	08:24:26	6.4	17.916° N	66.813° W	10.0
Jan. 7, 2020	08:34:02	5.6	17.922° N	66.731° W	10.0
Jan. 7, 2020	08:50:45	5.0	17.953° N	66.677° W	10.0
Jan. 7, 2020	11:18:43	5.6	18.022° N	66.776° W	9.0
Jan. 10, 2020	22:26:25	5.2	17.935° N	66.883° W	9.0
Jan. 11, 2020	12:54:45	5.9	17.949° N	66.851° W	5.0
Jan. 11, 2020	12:56:22	5.2	17.824° N	66.795° W	10.0
Jan. 15, 2020	15:36:23	5.2	17.916° N	67.017° W	5.0

# Overview



- Oblique strike-slip faulting.
- Very little historical seismicity in the region.
- Most activity just offshore, with maybe some slip apparent on the Punta Montalva fault.



# Aftershock forecast

← Latest Earthquakes

## M 6.4 - 14km SE of Guanica, Puerto Rico

2020-01-07 08:24:25 (UTC) | 17.862°N 66.829°W | 7.4 km depth

Overview

Interactive Map

Regional Information

Impact

Felt Report - Tell Us!

Did You Feel It?

ShakeMap

PAGER

Ground Failure

Technical

Origin

Moment Tensor

Waveforms

Aftershock Forecast

Download Event KML

View Nearby Seismicity

Earthquakes

Hazards

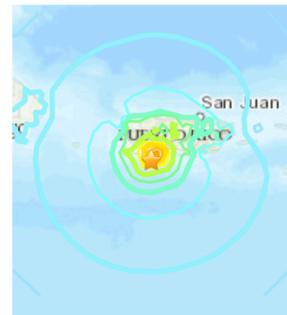
Data & Products

Learn

Monitoring

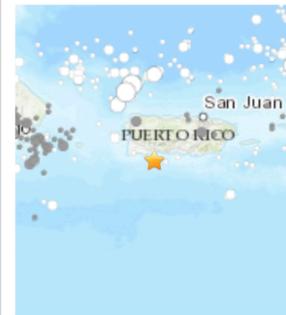
Research

Interactive Map



Contributed by US<sup>5</sup>

Regional Information



Contributed by US<sup>5</sup>

Felt Report - Tell Us!

0 0 2 4 9 0

Responses

Contribute to citizen science. Please [tell us](#) about your experience.

Citizen Scientist Contributions

Did You Feel It?

VIII

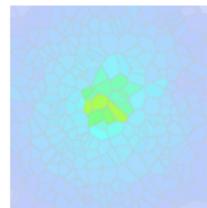


Community Internet Intensity Map

Contributed by US<sup>5</sup>

ShakeMap

VIII

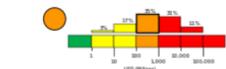


Estimated Intensity Map

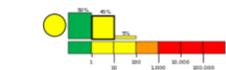
Contributed by US<sup>5</sup>

PAGER

ORANGE



Estimated Economic Losses



Estimated Fatalities

Contributed by US<sup>5</sup>

Ground Failure

Landslide Estimate

Little or no area affected  
Limited population exposed

Liquefaction Estimate

Limited area affected  
Limited population exposed

Contributed by US<sup>5</sup>

Origin

Review Status  
REVIEWED

Magnitude  
6.4 mww

Depth  
7.4 km

Time  
2020-01-07 08:24:25 UTC

Contributed by US<sup>5</sup>

Moment Tensor



Fault Plane Solution

Contributed by US<sup>5</sup>

Aftershock Forecast

Be ready for more earthquakes.

Our model of the expected numbers and odds of future earthquakes.

Contributed by US<sup>5</sup>

Tsunami



U.S. Tsunami Warning System

To view any current tsunami advisories for this and other events please visit <https://www.tsunami.gov>.

NOAA

View Nearby Seismicity

Time Range  
± Three Weeks

Search Radius  
250.0 km

Magnitude Range  
≥ 3.0

ANSS Comcat

- USGS issues aftershock forecasts after all M5.0 and larger earthquakes in the US.
- First forecast delivered within 30 minutes.
- Initial forecast is based on past sequences in this tectonic setting (average behavior and typical range).
- Forecast is updated frequently, observed aftershock are used to tune the forecast.

# Aftershock forecast

## Aftershock Forecast

Contributed by US<sup>5</sup> last updated 2020-02-25 23:49:36 (UTC)

- ✓ The data below are the most preferred data available
- ✓ The data below have been reviewed by a scientist

**Commentary**      Forecast      Model

### Be ready for more earthquakes

- More earthquakes than usual (called aftershocks) will continue to occur near the mainshock.
- When there are more earthquakes, the chance of a large earthquake is greater which means that the chance of damage is greater.
- The USGS advises everyone to be aware of the possibility of aftershocks, especially when in or around vulnerable structures such as unreinforced masonry buildings.
- This earthquake could be part of a sequence. An earthquake sequence may have larger and potentially damaging earthquakes in the future, so remember to: Drop, Cover, and Hold on.

### What we think will happen next

According to our forecast, over the next 1 Month there is a 3 % chance of one or more aftershocks that are larger than magnitude 6.4. It is likely that there will be smaller earthquakes over the next 1 Month, with 25 to 200 magnitude 3 or higher aftershocks. Magnitude 3 and above are large enough to be felt near the epicenter. The number of aftershocks will drop off over time, but a large aftershock can increase the numbers again, temporarily.

## M 6.4 - 14km SE of Guanica, Puerto Rico

2020-01-07 08:24:25 (UTC) | 17.862°N 66.829°W | 7.4 km depth

## Aftershock Forecast

Contributed by US<sup>5</sup> last updated 2020-02-25 23:49:36 (UTC)

- ✓ The data below are the most preferred data available
- ✓ The data below have been reviewed by a scientist

Commentary      **Forecast**      Model

Note: The expected rate of earthquakes continues to decline throughout the time windows. The probabilities in the longer time windows are higher only because the rates are being summed over a longer time period. These longer periods may be useful when planning recovery and rebuilding projects.

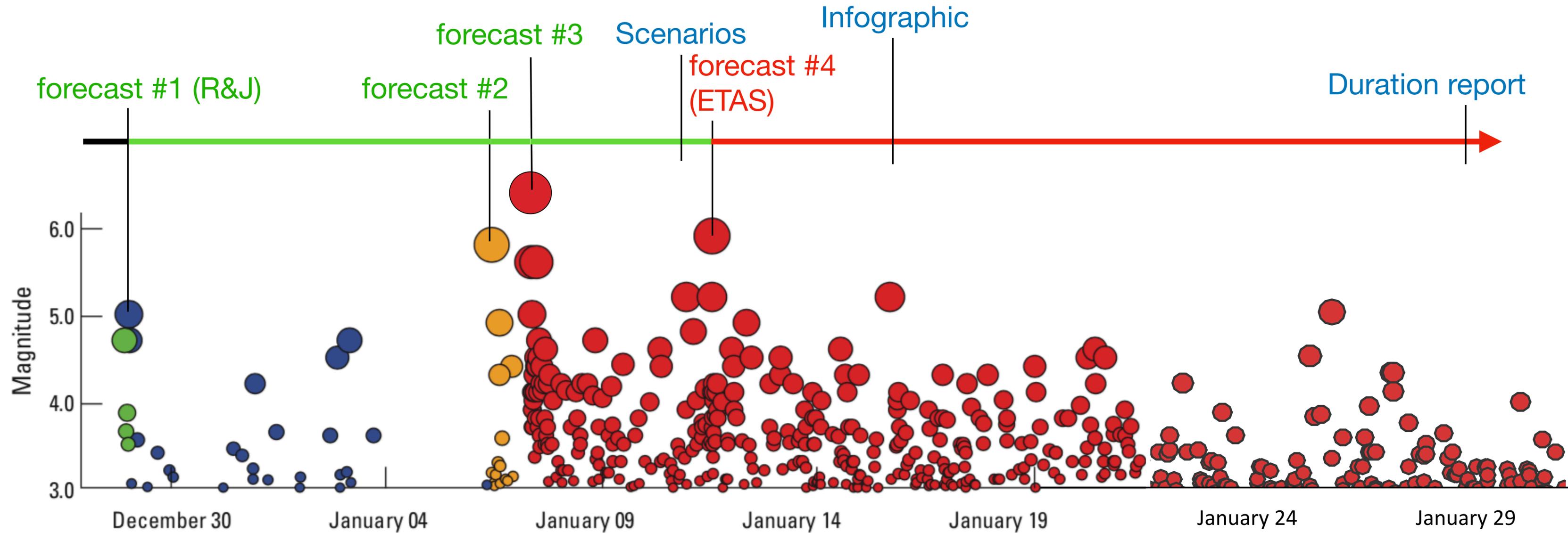
**The probability of at least one aftershock of at least magnitude M within the given time frame. Forecast starting 2020-02-25 23:59:59 (UTC)**

	1 Day	1 Week	1 Month	1 Year
M ≥ 3	87 %	> 99 %	> 99 %	> 99 %
M ≥ 5	2 %	14 %	43 %	91 %
M ≥ 6	< 1 %	2 %	6 %	26 %
M ≥ 7	< 1 %	< 1 %	< 1 %	3 %

**The likely number of aftershocks of at least magnitude M within the given time frame. Forecast starting 2020-02-25 23:59:59 (UTC)**

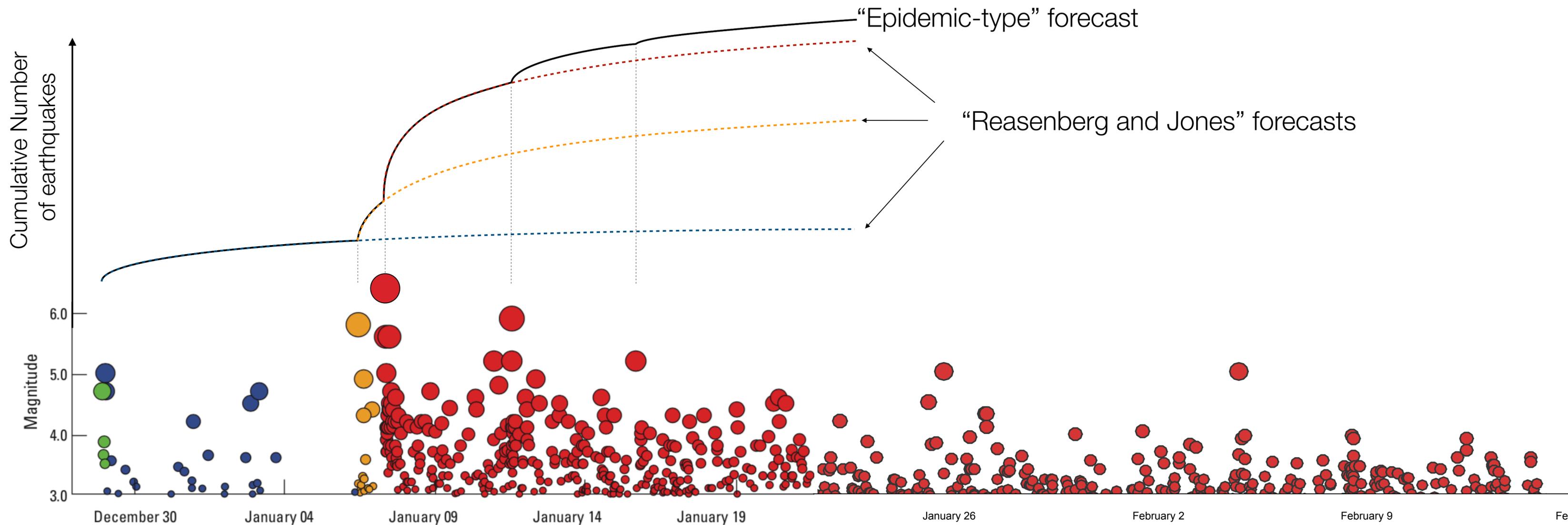
1 Day      1 Week      1 Month      1 Year

# Forecast timeline



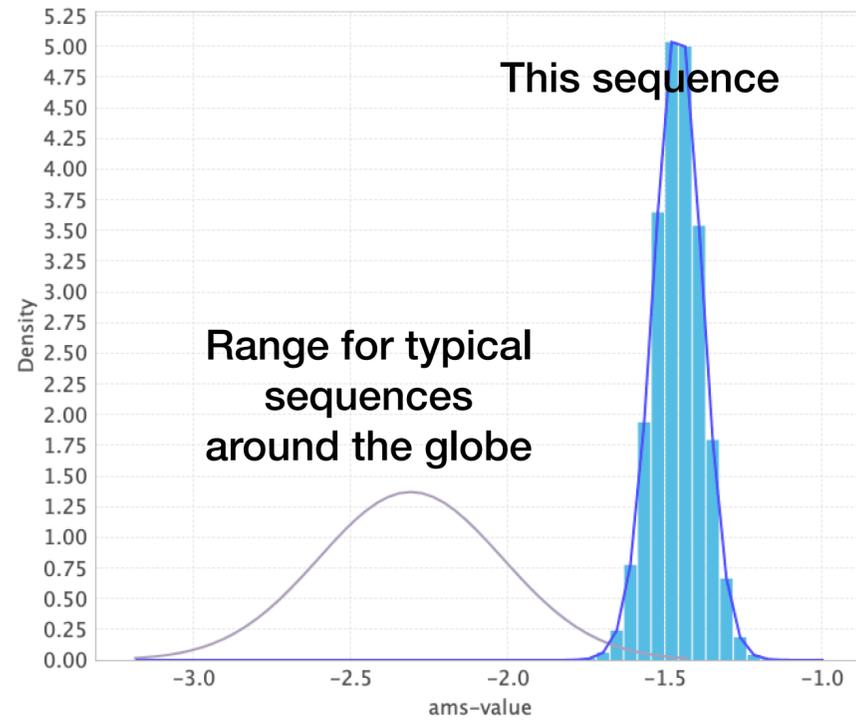
# Forecast models

- Default forecast model is “Reasenberg and Jones” (1989) — runs automatically, but can only handle typical mainshock-aftershock sequences, needs to be reset after each large aftershock.
- Switched to “Epidemic-Type Aftershock Sequence” model after M5.9 aftershock on January 11th. — considers combined aftershocks from multiple large earthquakes, but not set up to run automatically.



# Forecast details

## Mainshock (M6.4) Primary productivity



- The one-week chance of a M6+ was 2% at the time of the Jan 7th M6.4 mainshock.

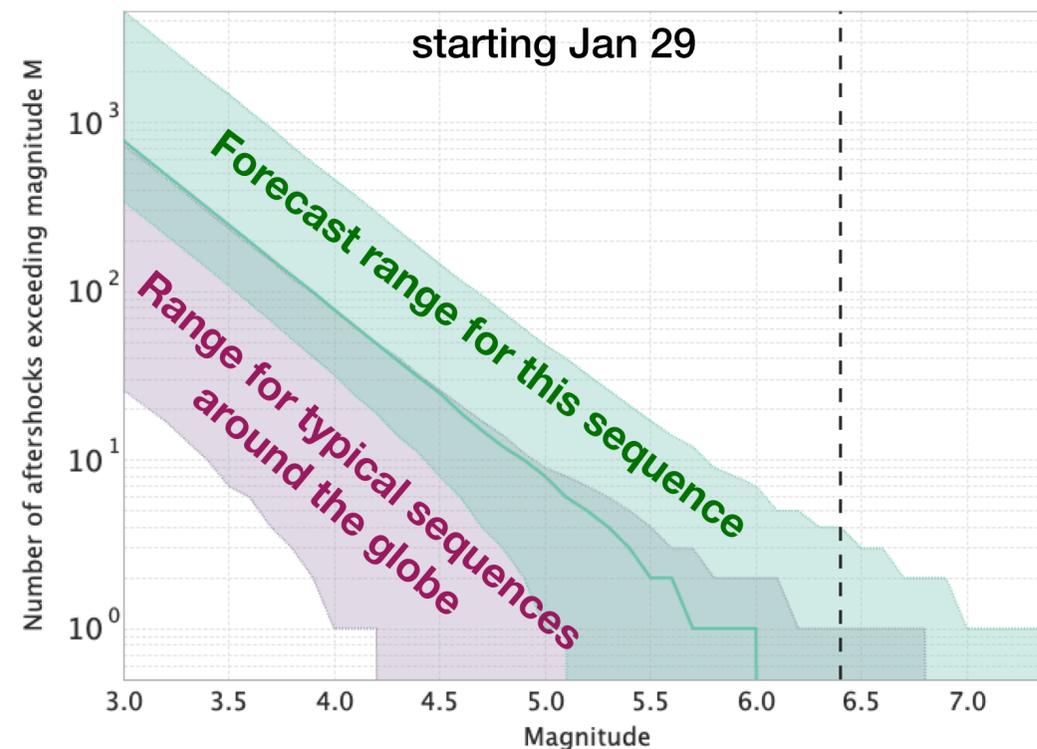
- The M6.4 mainshock (and the sequence overall) has been unusually productive.

- In the top 2.3%\* of the last 2700 recorded M6+ earthquakes worldwide

\*(ranked according to # of aftershocks within 1.5 magnitude units of the mainshock, in the first 25 days)

- 9 magnitude 5+ aftershocks so far (Ridgecrest M7.1 triggered only 4)

## one-year forecast with uncertainty



## Scenarios

## Infographics

### Escenarios de terremotos en Puerto Rico

Release Date: JANUARY 11, 2020

Los terremotos, como los ocurridos en Puerto Rico, pueden ser preocupantes, destructivos y en muchas ocasiones trágicos para las comunidades afectadas.

Última actualización

Esta es la razón por la que los recursos de emergencia se activan ante las amenazas. Aquí se ofrecen los datos más recientes de 2020.

Además a los ciudadanos se les ofrecen las posibles opciones de evacuación.

Acerca de

Según nuestros datos, los temblores de magnitud 6.0 o superior ocurren desde una vez cada 10 años en promedio. Los escenarios de terremotos de magnitud 6.0 o superior del escenario de las réplicas de un terremoto de magnitud 7.0 o superior.

Escenarios durante

El escenario de un terremoto de magnitud 6.0 o superior y que no ocurra un terremoto de magnitud 7.0 o superior especialmente durante un terremoto de magnitud 7.0 o superior se puede considerar un escenario de alta probabilidad.

Escenarios de los próximos meses

Un escenario de un terremoto de magnitud 6.0 o superior como un "doublet" podría causar un terremoto de magnitud 7.0 o superior.

### Earthquake Scenarios for Puerto Rico

Release Date: JANUARY 11, 2020

Earthquakes are unsettling, destructive, and often tragic to the communities they affect. The USGS works diligently to help keep people safer by providing them and their emergency responders the science needed to respond to ongoing hazards.

**Last updated February 25, 5pm Pacific time, 2020. Next update will be on March 25.**

#### About the scenarios

Here are the three most likely scenarios for how this earthquake sequence will evolve over the next 30 days based on our [aftershock forecasts](#). **These scenarios describe three possibilities of what could happen from February 26 to March 26.** Only one of these scenarios will occur within the next month. These scenarios will change over time, like our forecast.

The earthquakes in these scenarios would occur in the areas where aftershocks are happening now. Earthquakes in this sequence will continue to occur for days, months, or potentially years to come. It is very unlikely the aftershocks will cease completely within the next month.

#### Scenario One (Most likely): 94 percent within the next 30 days

The **most likely scenario** is that aftershocks will continue to decrease in frequency over the next 30 days and will be significantly lower in magnitude than the M6.4 that occurred on the 7 January 2020 (i.e., will be less than M6.0). Some of these moderately sized aftershocks (M5.0+) may cause localized damage, particularly in weak structures. Smaller magnitude earthquakes (M3.0+), when at shallow depth, may be felt by people close to the epicenters.

#### Scenario Two (Less likely): 6 percent within the next 30 days

A less likely scenario is an earthquake occurring of similar size as the M6.4 event. This is called a "doublet": when two large earthquakes of similar size occur closely in time and location. This earthquake could cause additional damage in the same region and increases the number of aftershocks.

#### Scenario Three (Least likely): <1 percent within the next 30 days

A much less likely scenario than the previous two scenarios is that recent earthquakes could trigger an earthquake significantly larger than the M6.4 that occurred on the 7 January (i.e., M7.0 and above). While this is a very small probability, if such an earthquake were to occur, it would have serious impacts on communities nearby. This size earthquake would also trigger its own aftershock sequence, so the rate of small and moderate earthquakes would increase again.

**USGS**  
science for a changing world

## Secuencia del Terremoto en Puerto Rico, 2020

Terremotos detectados entre diciembre 28, 2019, y enero 16, 2020.

**>300 M3+** terremotos\* registrados desde dic 28, 2019 (dentro de 40km) suficientemente fuerte como para ser sentido

**10 M5+** terremotos\* registrados desde dic 28, 2019 (incluyendo M6.4) lo suficientemente fuerte como para dañar

\* Data hasta 2020-01-16 19:38-30 (UTC)

**USGS**  
science for a changing world

## 2020 Puerto Rico Earthquake Sequence

Earthquakes detected between December 28, 2019 as of January 16, 2020. Subject to updates.

M5.0	M5.8	M6.4	M5.9
10km S of Indios, Puerto Rico	13km SSE of Indios, Puerto Rico	8km S of Indios, Puerto Rico	13km SE of Guanica, Puerto Rico
2019-12-29 01:06:00 (UTC)	2020-01-06 10:32:18 (UTC)	2020-01-07 08:24:26 (UTC)	2020-01-11 12:54:45 (UTC)
486 Responses Did You Feel It?	934 Responses Did You Feel It?	2,420 Responses Did You Feel It?	1,302 Responses Did You Feel It?

\* Data as of 2020-01-16 19:38-30 (UTC)

Un agradecimiento especial a nuestro colaborador del Sistema Sismológico Nacional Avanzado (ANS), la Red Sísmica de Puerto Rico (PRSN) en la Universidad de Puerto Rico en Mayagüez.

Superior izquierda: el científico Jim Smith, trabajando en el cableado dentro de la represa Luccchetti en Puerto Rico, septiembre de 2019, ayudando al Programa de Movimiento Fuerte de Puerto Rico en los esfuerzos de recuperación del Huracán María.

Inferior medio: José Cancel de la Red Sísmica de Puerto Rico (PRSN), Alena Leeds del USGS y Javier Santiago de PRSN instalan un sismómetro en Sabana Yeguas en el suroeste de Puerto Rico el 10 de enero, 2020.

Trasfondo y derecha: daños en Puerto Rico, enero, 2020.

U.S. Department of the Interior  
U.S. Geological Survey

A special thanks to our Advanced National Seismic System (ANSS) partner, the Puerto Rico Seismic Network (PRSN) at University of Puerto Rico at Mayagüez.

Top left Scientist, Jim Smith, working on cabling inside of Luccchetti dam in Puerto Rico back in September 2019, assisting the Puerto Rico Strong Motion Program with Hurricane María recovery efforts.

Bottom middle: Jose Cancel of Puerto Rico Seismic Network (PRSN), Alena Leeds of USGS and Javier Santiago of PRSN install a temporary seismometer at Sabana Yeguas in southwestern Puerto Rico on Jan. 10, 2020.

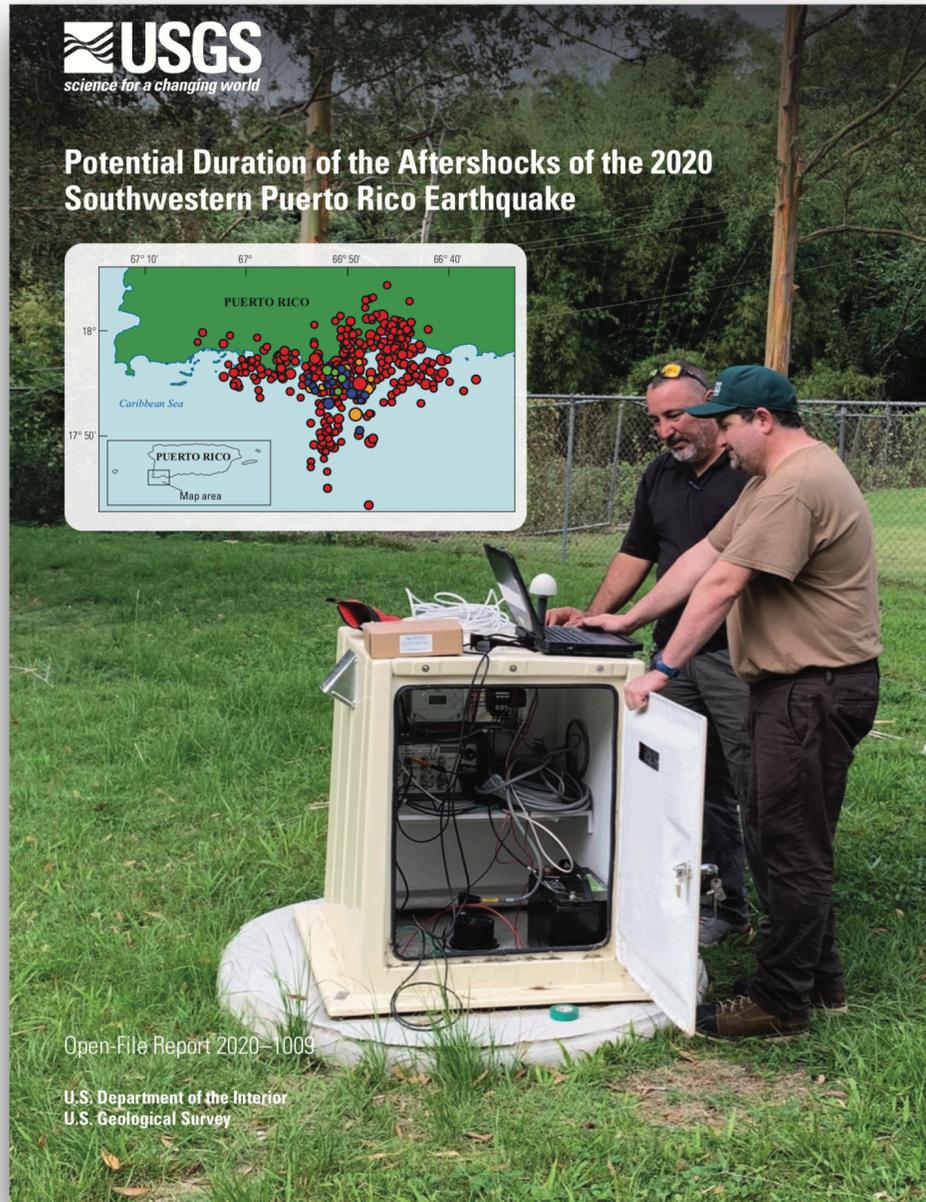
Background and right: Puerto Rico damage January 2020.

U.S. Department of the Interior  
U.S. Geological Survey

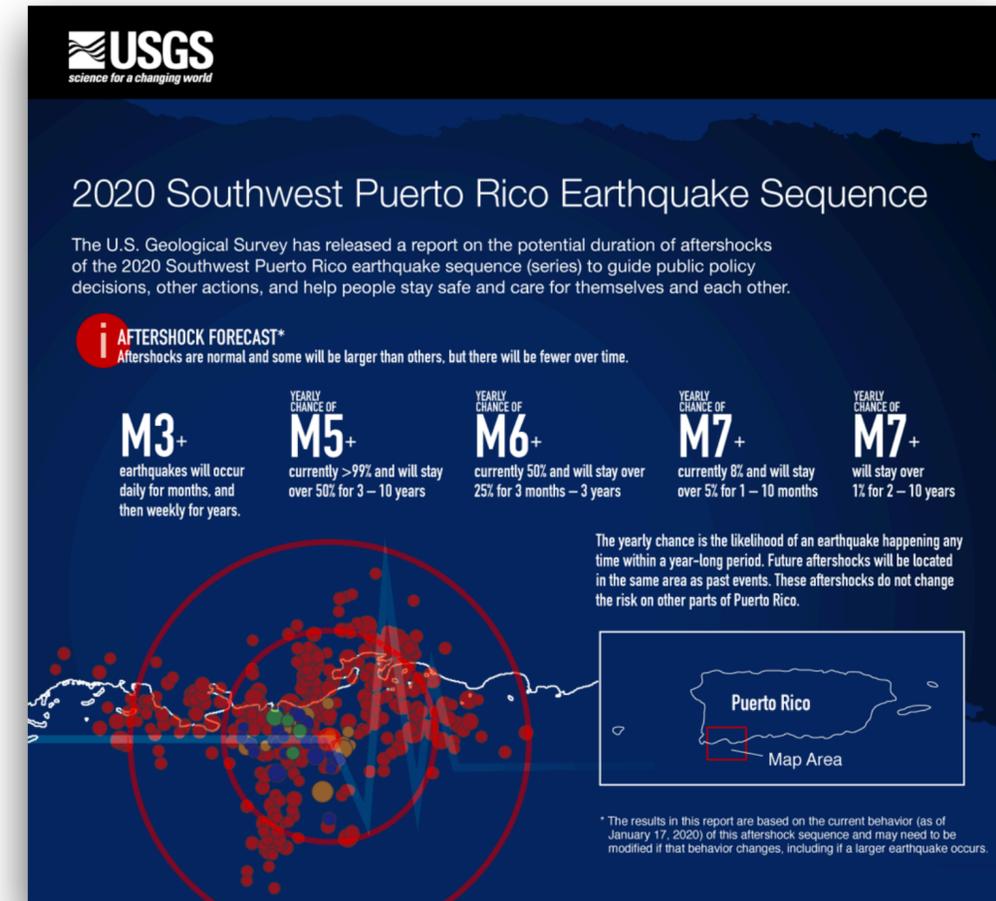
**SCIENCE IN ACTION**

**i** M6.4 Earthquake Forecast Information [www.usgs.gov/pr-2020](http://www.usgs.gov/pr-2020)

# Duration report



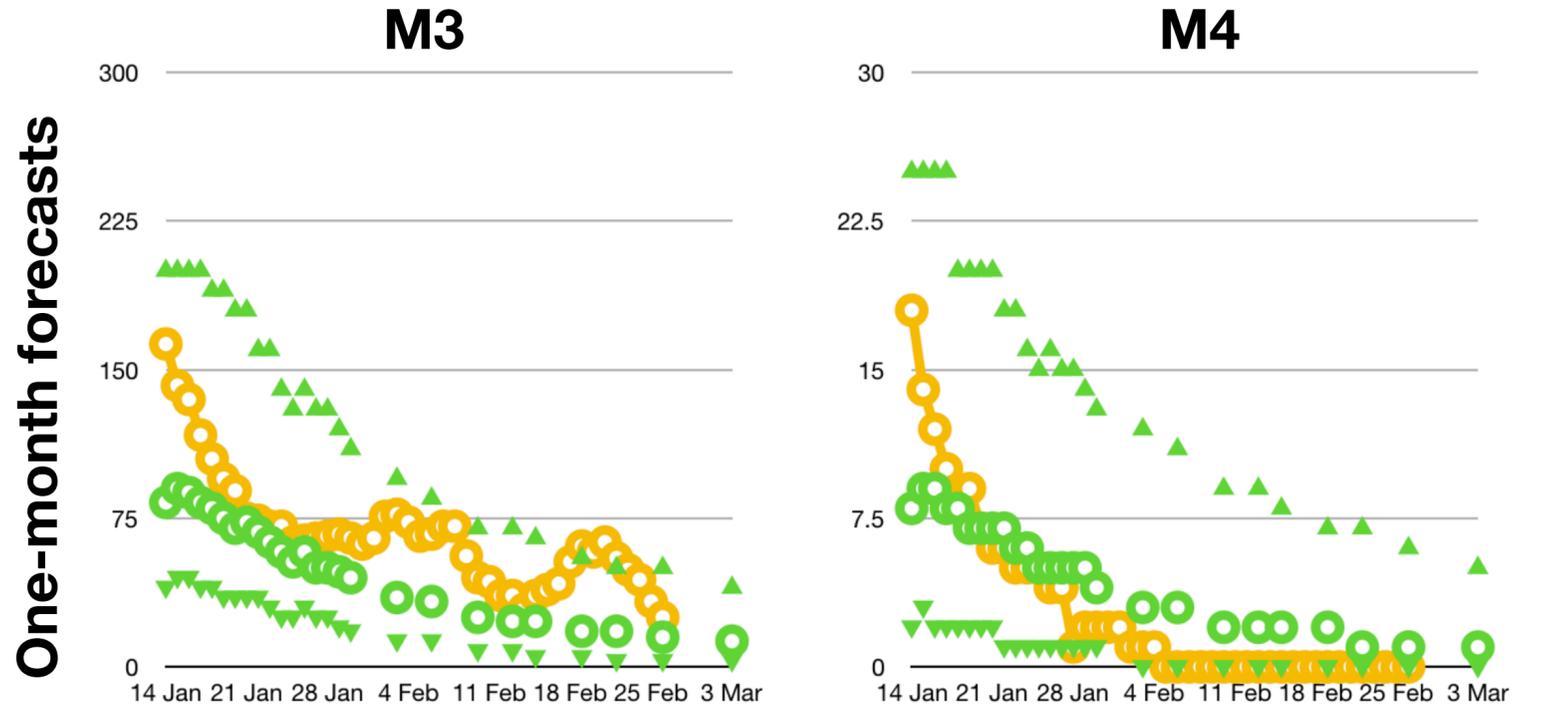
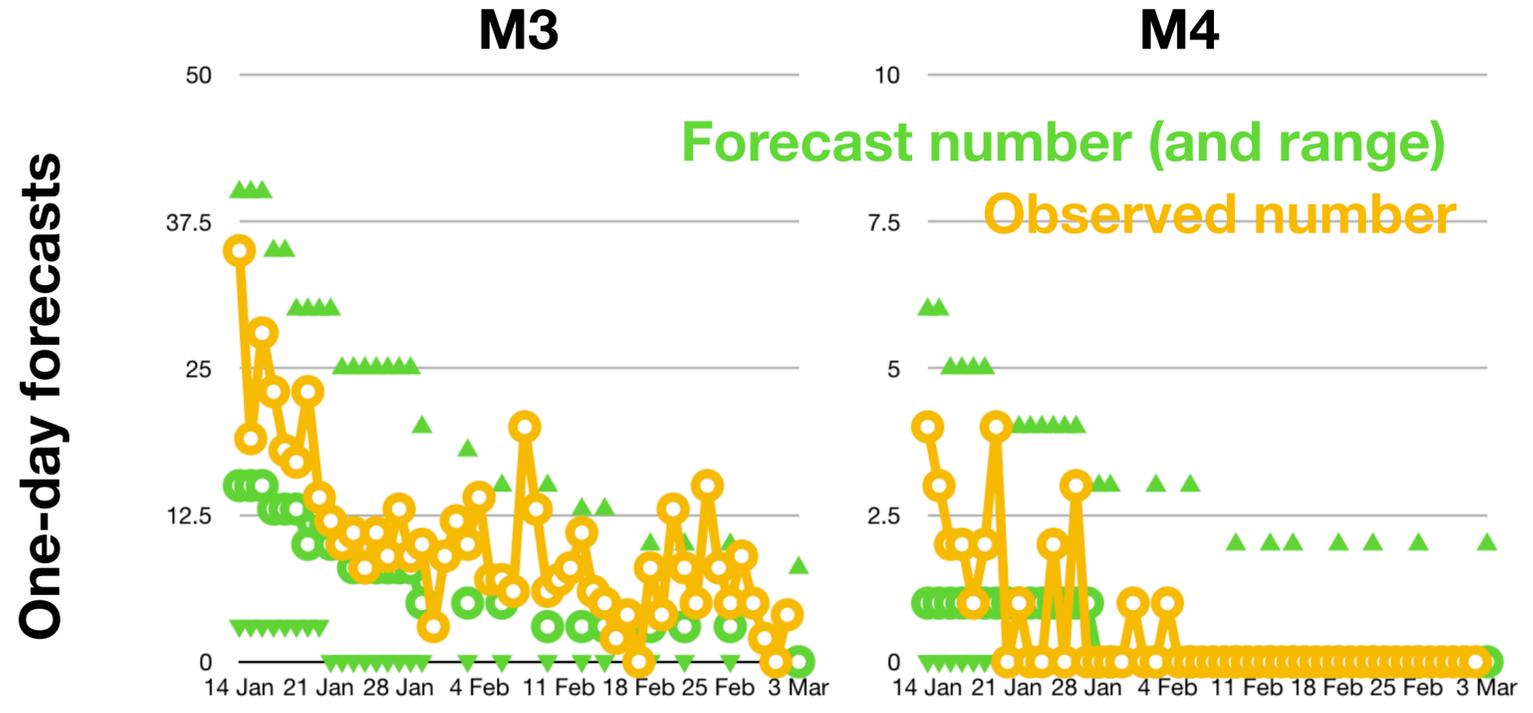
- FEMA requests information on how long earthquakes are likely to persist.
- “Duration Report” based on 10-year forecast extrapolation.
- Published in English and Spanish.
- Briefed PR Government and Emergency Managers on Jan 29th.
- As of Jan 17th:
  - Yearly chance of M5 will remain above 50% for 3 – 10 years
  - Chance of M6 will remain above 25% for 3 months – 3 years
  - Chance of M7 will remain above 5% for 1 – 10 months



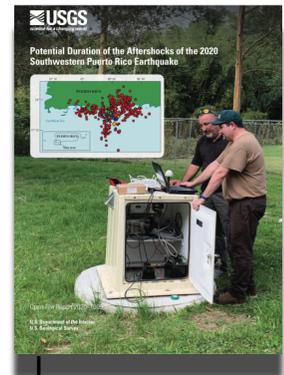
**Table 2.** Expected duration for earthquakes occurring on a regular basis<sup>1</sup> after January 17, 2020<sup>2</sup>.

Frequency of earthquakes	Magnitude 3 or greater	Magnitude 4 or greater
Daily	2–6 months	5–13 days
Weekly	1.5–10 years	4–16 months
Monthly	10 or more years	1.5–10 years

# Forecast performance

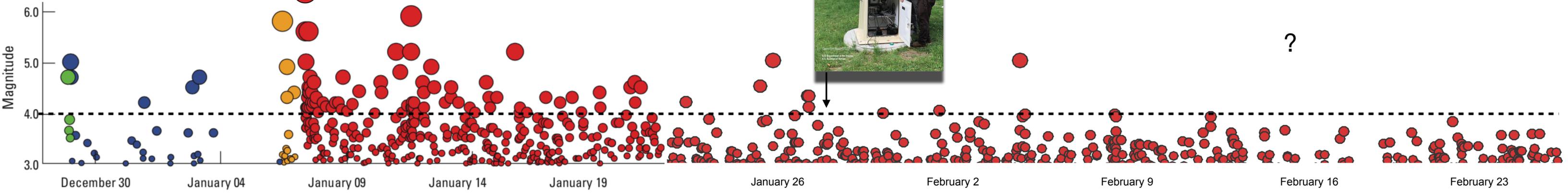


Duration report:



“weekly M4’s for four or more months”

?



# Conclusion

- The 2019-2020 Southwestern Puerto Rico aftershock sequence has been particularly productive.
- USGS issued first forecast 30 minutes after the Dec. 29th M5, has been updating the forecast regularly since.
- Forecast communicated via the USGS website, press releases, social media, infographics, and an Open-File Report.
- Chance of further aftershocks remains high, but sequence may be decaying faster than anticipated.

## Anticipated aftershock activity

Forecast start date: 2 Mar 2020, 23:59 UTC

