EAS 4801 - Planetary Sound
Lec#4: Varying sound speeds and standing waves

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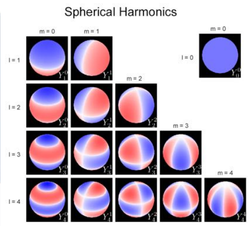
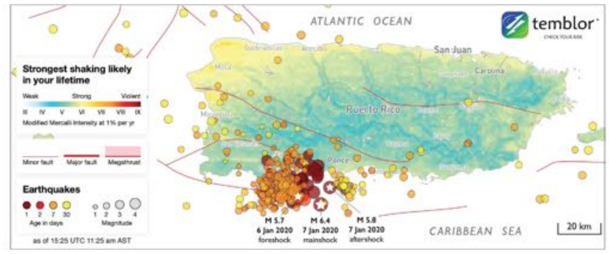
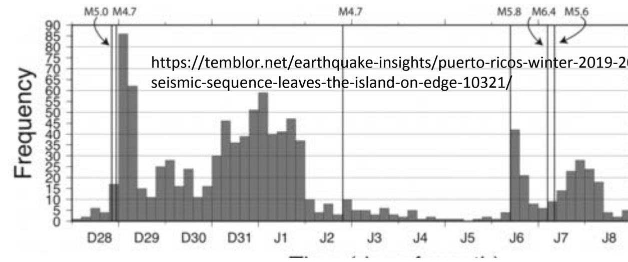
01/10/2020
Spring 2020

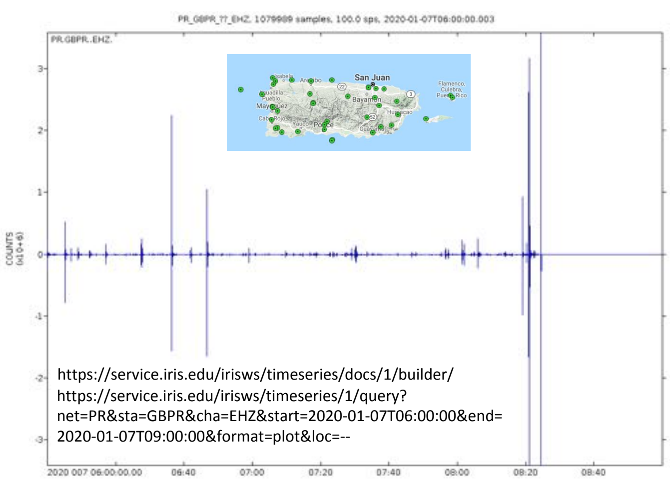

U.S. Navy F/A-18 approaching the sound barrier. The white cloud forms as a result of the supersonic expansion fans dropping the air temperature below the dew point.[1][2]



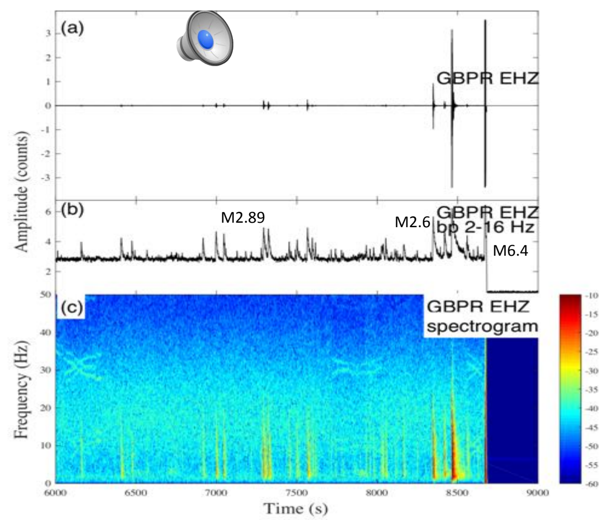




https://temblor.net/earthquake-insights/puerto-ricos-winter-2019-2020-seismic-sequence-leaves-the-island-on-edge-10321/

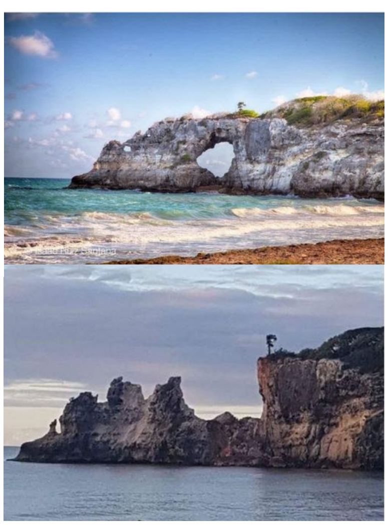


https://service.iris.edu/irisws/timeseries/docs/1/builder/
https://service.iris.edu/irisws/timeseries/1/query?net=PR&sta=GBPR&cha=EHZ&start=2020-01-07T06:00:00&end=2020-01-07T09:00:00&format=plot&loc=--




A house in southern Puerto Rico in the municipality of Guánica that was built upon stilts. The columns buckled during the shaking caused by the M 5.8 earthquake just offshore on January 6, 2020. This is a classic 'soft first story" building. Photo credit: Fernando Martínez Torres.

Soft-Story Building



Before and after views of the Punta Ventana in Guayanilla. Shaking during the M 5.8 event on January 6, 2020 caused its collapse. Photo credit: twitter.com/UPRMetLab/

30-Day Aftershock Scenarios (Revised: Jan 12; English | Spanish)

Based on our aftershock forecasts, USGS has modeled three possible scenarios for this earthquake sequence as it evolves over the next month. These scenarios represent what could happen from January 12 to February 12, 2020. Only one of these scenarios will occur. The earthquakes in these scenarios would occur in the areas near where aftershocks are happening now. Regardless of scenario, earthquakes 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.

https://www.usgs.gov/news/magnitude-64-earthquake-puerto-rico

Scenario One (most likely): 76 percent chance

The most likely scenario is that aftershocks will continue to decrease in frequency over the next 30 days, with no further earthquakes similarly sized to the M 6.4 that occurred on Jan. 7, 2020 (i.e., will be less than M 6.0). Some of these moderately sized aftershocks (M 5.0+) may cause localized damage, particularly in weak structures. Smaller magnitude earthquakes (M 3.0+), when at shallow depth, may be felt by people close to the epicenters.

Scenario Two (less likely): 21 percent chance

A less likely scenario is an earthquake occurring of similar size as the M 6.4 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): 3 percent chance

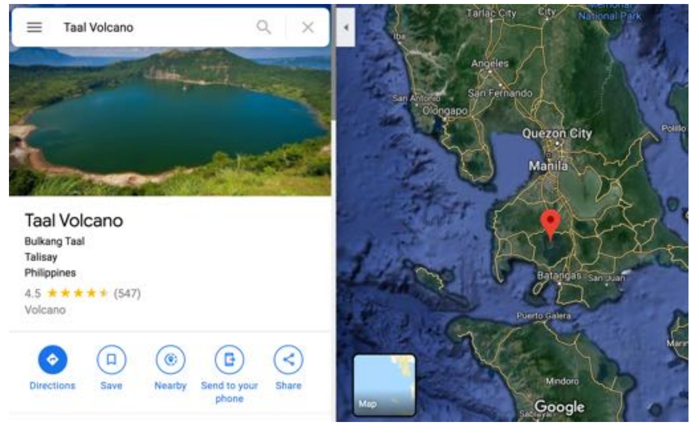
A much less likely scenario than the previous two scenarios is that recent earthquakes could trigger an earthquake significantly larger than the M 6.4 that occurred Jan. 7, 2020 (i.e., M 7.0 and above). While this is a small probability, if such an earthquake were to occur, it would have serious impacts on communities nearby. This sized earthquake would also trigger its own aftershock sequence, so the rate of small and moderate earthquakes would increase again.

Philippines warns of 'explosive eruption' Volcano spews ash near Manila

By Jinky Jorgio, Jessie Yeung and Alaa Elassar, CNN

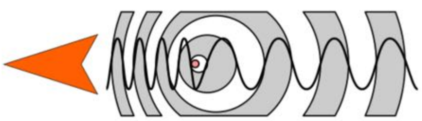
Updated 7:14 AM ET, Mon January 13, 2020

Taal Volcano (Alert level 4): explosive eruption could happen in the next hrs or days



Doppler Effect

- The Doppler effect (or the Doppler shift) is the change in frequency of a wave in relation to an observer who is moving relative to the wave source.



https://upload.wikimedia.org/wikipedia/commons/9/90/Speeding-car-horn_doppler_effect_sample.ogg
https://en.wikipedia.org/wiki/Doppler_effect

Doppler Equation

$$f_L = f_S\left(\frac{v \pm v_L}{v \pm v_S}\right)$$

f_L = frequency as heard by a listener

f_S = frequency produced by the source

v = speed of sound in the medium

v_L = speed of the listener

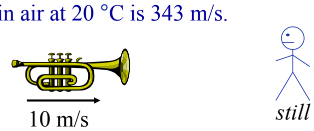
v_S = speed of the source

This equation takes into account the speed of the source of the sound, as well as the listener's speed, relative to the air (or whatever the medium happens to be). The only tricky part is the signs. First decide whether the motion will make the observed frequency higher or lower. (If the source is moving toward the listener, this will increase f_L, but if the listener is moving away from the source, this will decrease f_L.) Then choose the plus or minus as appropriate. A plus sign in the numerator will make f_L bigger, but a plus in the denominator will make f_L smaller. Examples are on the next slide.

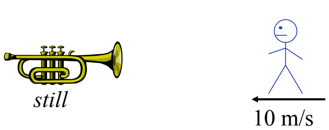
Doppler Set-ups

$$f_L = f_S\left(\frac{v \pm v_L}{v \pm v_S}\right)$$

The horn is producing a pure 1000 Hz tone. Let's find the frequency as heard by the listener in various motion scenarios. The speed of sound in air at 20 °C is 343 m/s.



$$f_L = 1000\left(\frac{343}{343 - 10}\right) = 1030 \text{ Hz}$$



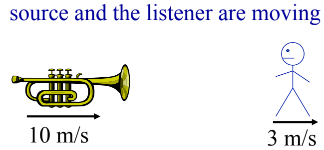
$$f_L = 1000\left(\frac{343 + 10}{343}\right) = 1029 \text{ Hz}$$

Note that these situation are <u>not</u> exactly symmetric.
Also, in real life a horn does not produce a single tone.
More examples on the next slide.

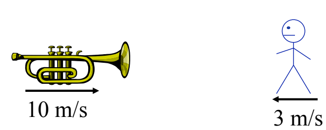
Doppler Set-ups (cont.)

$$f_L = f_S\left(\frac{v \pm v_L}{v \pm v_S}\right)$$

The horn is still producing a pure 1000 Hz tone. This time both the source and the listener are moving with respect to the air.



$$f_L = 1000\left(\frac{343 - 3}{343 - 10}\right) = 1021 \text{ Hz}$$



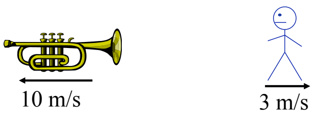
$$f_L = 1000\left(\frac{343 + 3}{343 - 10}\right) = 1039 \text{ Hz}$$

Note when they're moving toward each other, the highest frequency possible for the given speeds is heard. Continued . . .

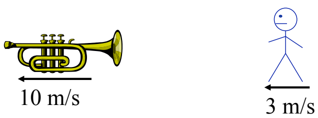
Doppler Set-ups
(cont.)

$$f_L = f_S\left(\frac{v \pm v_L}{v \pm v_S}\right)$$

The horn is still producing a pure 1000 Hz tone. Here are the final two motion scenarios.



$$f_L = 1000\left(\frac{343 - 3}{343 + 10}\right) = 963 \text{ Hz}$$



$$f_L = 1000\left(\frac{343 + 3}{343 + 10}\right) = 980 \text{ Hz}$$

Note the when they're moving toward each other, the highest frequency possible for the given speeds is heard. Continued . . .

Doppler Problem

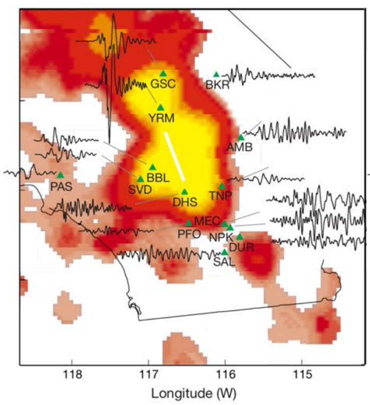
Mr. Magoo & Betty Boop are heading toward each other. Mr. Magoo drives at 21 m/s and toots his horn (just for fun; he doesn't actually see her). His horn sounds at 650 Hz. How fast should Betty drive so that she hears the horn at 750 Hz? Assume the speed of sound is 343 m/s.

$$f_L = f_S\left(\frac{v \pm v_L}{v \pm v_S}\right) \qquad 750 = 650\left(\frac{343 + v_L}{343 - 21}\right)$$

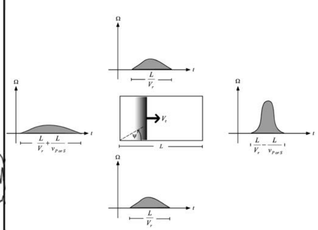
$$v_L = 28.5 \text{ m/s}$$

21 m/s → ← v_L

Earthquake Directivity Effect



Gomberg et al. (Nature, 2001)

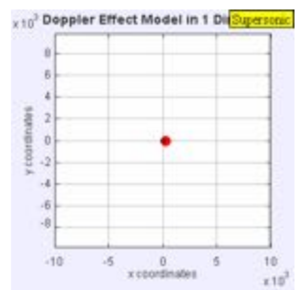


Ben-Zion (2003)

Supersonic Speed

Supersonic travel is a rate of travel of an object that exceeds the speed of sound (Mach 1). For objects traveling in dry air of a temperature of 20 °C (68 °F) at sea level, this speed is approximately 344 m/s,

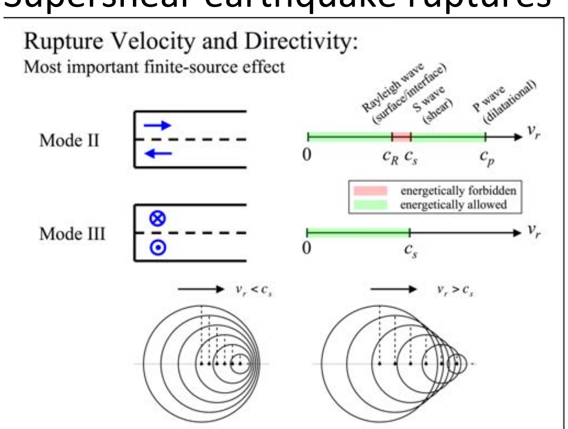
Speeds greater than five times the speed of sound (Mach 5) are often referred to as hypersonic.



U.S. Navy F/A-18 approaching the sound barrier. The white cloud forms as a result of the supersonic expansion fans dropping the air temperature below the dew point.[1][2]

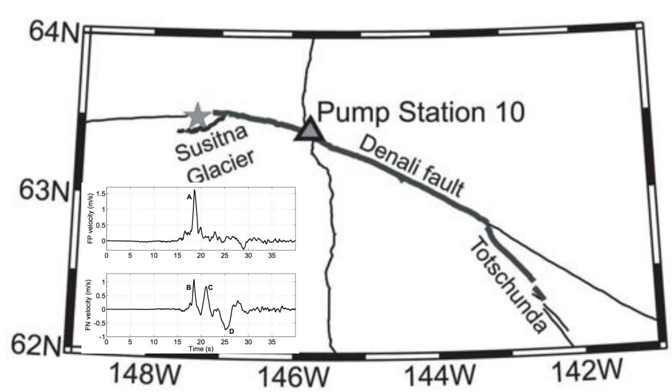
https://en.wikipedia.org/wiki/Supersonic_speed

Supershear earthquake ruptures



http://pangea.stanford.edu/~edunham/research/supershear.html

2002 M7.8 Denali Fault Earthquake



THE TRANS-ALASKA OIL PIPELINE SURVIVES THE QUAKE—A TRIUMPH OF SCIENCE AND ENGINEERING

https://pubs.usgs.gov/fs/2003/fs014-03/pipeline.html