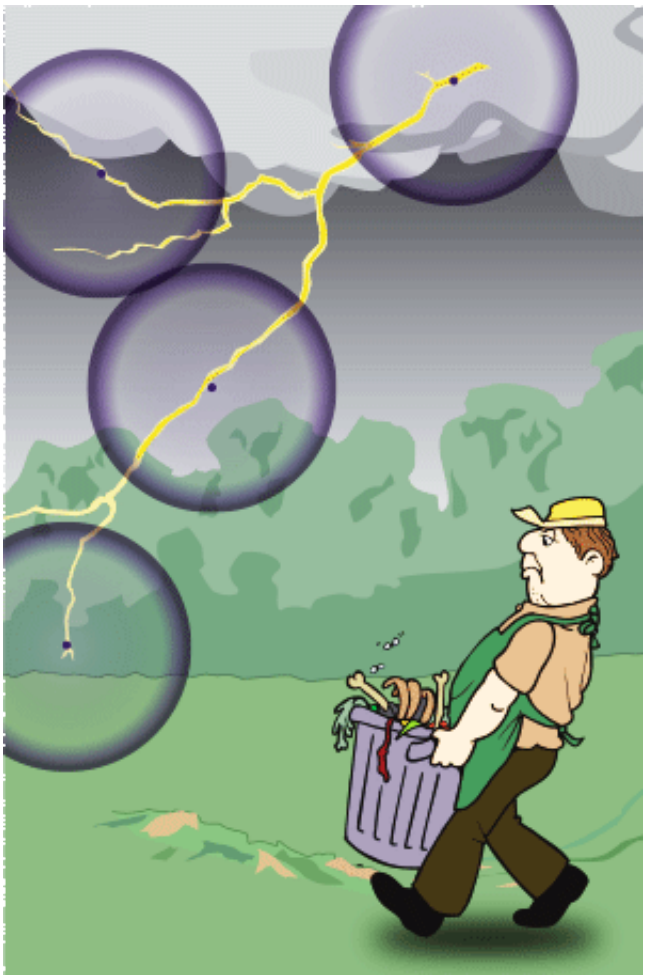
National Oceanic and
Atmospheric Administration
U.S. Department of Commerce

The Sound of Thunder

Thunder is the acoustic shock wave resulting from the extreme heat generated by a lightning flash. It is produced the same way regardless of whether lightning is positive or negative.

Lightning can be as hot as 54,000°F (30,000°C), a temperature that is five times hotter than the surface of the Sun! When lightning occurs, it heats the air surrounding its channel to that same incredible temperature in a fraction of a second.

Like all gases, air expands when heated. The faster it is heated, the faster the rate of expansion. When air is heated to 54,000°F (30,000°C) in a fraction of a second, a phenomenon known as "explosive expansion" occurs – air expands so rapidly that it compresses the air in front of it, forming a shock wave similar to a sonic boom. Exploding fireworks produce a similar result.



When lightning strikes, a shock wave is generated at each point along the path of the lightning bolt (The above illustration shows only four points). When the shock wave is first created, there is a sharp boundary associated with it.
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The initial sound reaches the ear with a loud bang, crack, or snap.
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As shock waves propagate away from the path of the lightning bolt, they are distorted, becoming stretched and elongated. The sound is more muted. Other shock waves from more distant locations arrive at the listener. Shock waves emanating along the lightning bolt's path and arriving at the listener's ear at the same time enhance the intensity of the sound.
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At large distances from the center, the shock wave (thunder) is greatly elongated and can be many miles across. The combination of millions of shock waves gives thunder the continuous booming/rumbling sound we hear.
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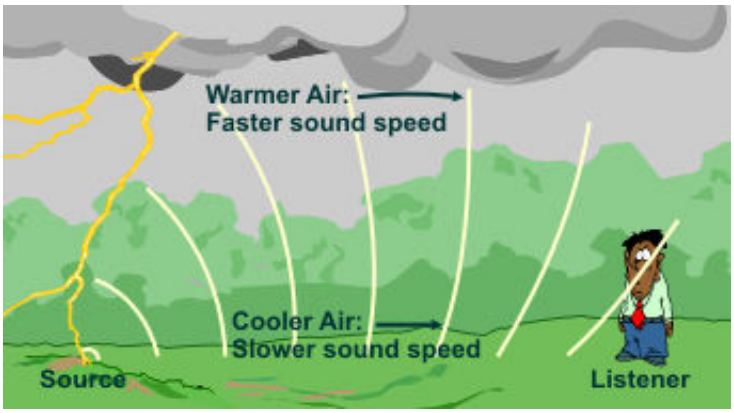
Learning Lesson: The Rumblin' Road: Determining Distance to a Thunderstorm

The temperature of the atmosphere affects the sound of thunder as well as how far it travels.

Sound waves move faster in warm air than in cool air. Typically, the air temperature decreases with height, and thunder will normally have an audible range up to 10 miles (16 km).



How sound waves travel through cool and warm air
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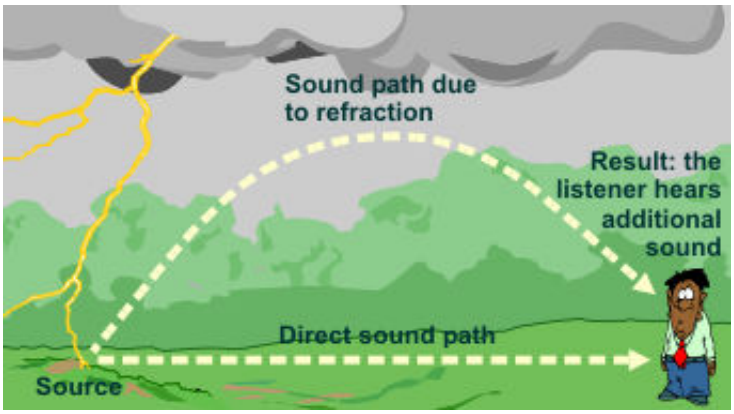
However, when the air temperature increases with height, called an inversion, sound waves are refracted (bent back toward the Earth) due to their faster motion in the warmer air. Normally, only the direct sound of thunder is heard. But refraction can add some additional sound, effectively amplifying the thunder and making it sound louder.

This is more common in the winter, when thunderstorms develop in the warm air above a cooler surface air mass.

If the lightning in these "elevated thunderstorms" remains above the inversion, then most of the thunder sound also remains above the inversion. However, many of the sound waves from cloud-to-ground strikes remain below the inversion, giving thunder a much louder impact.



How warm and cool air affect the sound of thunder.
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