NGSS Air Quality
Science Activity

INVERSION LAYER INVESTIGATION

EXPLORE HOW WEATHER IMPACTS AIR POLLUTION

Our Planet is a Classroom

kids making sense

Inversion Layer and Pollution Investigation

One way that weather impacts air pollution levels

Introduction

Air quality is not only affected by how much pollution is being produced - it is also impacted by the weather, which influences how pollutants move around in the atmosphere. Both wind and temperature can impact whether pollutants accumulate (build up) or disperse (spread out) in an area. Calm winds allow pollutants to accumulate near sources of pollution, while stronger winds can disperse pollutants and bring cleaner air into a region.

The difference in air temperatures near the surface of the Earth and higher up in the atmosphere can be even more important than wind in determining how much pollution accumulates or disperses in the air. This activity goes into the details of how temperature differences can impact air quality.

Next Generation Science Standards:

Standard	Description	Grade
MS-ESS2-5 Earth's Systems	Collect data to provide evidence for how the motions and complex interactions of air masses result in changes in weather conditions.	Middle School (6-8)
HS-ESS2-2 Earth's Systems	Analyze geoscience data to make the claim that one change to Earth's surface can create feedback that cause changes to other Earth systems.	High School (9-12)
HS-ESS3-6 Earth and Human Activity	Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.	High School (9-12)

Daytime Temperatures

As the sun heats the surface of the Earth, the air just above the ground also warms up. As air warms, it becomes less dense than the cooler air above it, so it rises upward like the steam over a pot of boiling water. In the atmosphere, this upward motion causes the air to mix. How does air mixing relate to pollution? On a warm, sunny day, the more polluted air near the surface can mix with cleaner air above it, leading to lower pollutant concentrations near the surface. Don't forget that the air near the surface of the Earth is the air we breathe, so mixing air improves our air quality!

What Are Temperature Inversions?

As the sun sets on clear, calm nights, the ground begins to cool quickly. As the air near the ground cools, it becomes more dense than the warmer air above, which prevents the air from mixing. This layering of warmer air above cooler air is called a **temperature inversion**.

How Do Temperature Inversions Impact Air Quality?

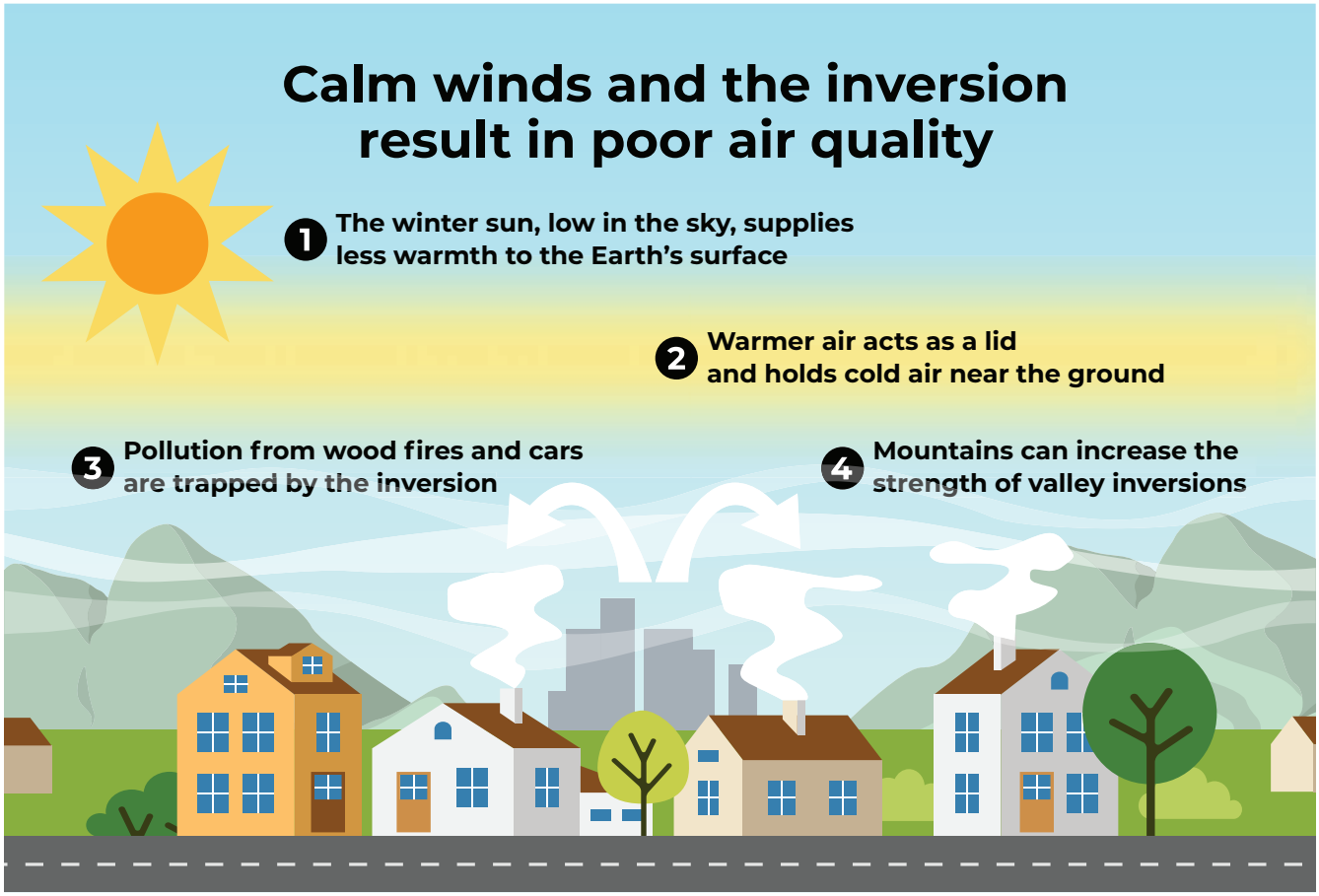
Temperature inversions limit the air from mixing in the lower levels of the atmosphere. This is because the cool air does not want to travel upwards, and the warm air does not want to travel downwards – so the air layers are stable and tend to stay where they are. But how does this impact air quality? Pollutants produced near the Earth's surface will also get trapped near the ground with the colder air! Temperature inversions are more common in the winter, when longer nights allow the Earth's surface to cool for longer periods, and because there is less sunlight to warm the ground. During the winter months, people sometimes burn wood or other materials to stay warm. Smoke from these fires can build up and become trapped with a temperature inversion, which can lead to poor air quality. Additionally, snow cover during the winter can strengthen temperature inversions because the snow further cools the near-surface air.

Temperature inversions can also persist into the daytime, especially when low clouds are blocking the sun and preventing the sun from warming the atmosphere.

More Detail
How does air temperature affect air density?

If you've ever watched the air over a pot of boiling water, you already have witnessed how air temperature and density are related. The air over a pot of boiling water rises because it is warmer and therefore less dense than the surrounding air. The opposite is true of cold air. If you were to open a freezer door barefoot, you would notice the air sinking toward your feet, because it is more dense.

Summary: Hot air rises because it is less dense than the surrounding cooler air. Cold air sinks because it is more dense than the surrounding warmer air.



What Can We Do?

Across the country, it is common to implement "no burn days" on days when air quality is already forecasted to be poor, and also during times when inversion layers are forecast. On these days, local air quality agencies ask residents to stop burning wood or reduce activities that might contribute to air pollution for the day. Activities may include burning wood in a fireplace, backyard fire pits, wood stoves, and BBQs, and in some cases, driving.
Your local air quality agency may have a name for the program, such as "Spare the Air" or "Check Before You Burn." To find out if your local air district has a "no burn day" program, follow the steps below:

To Find Your Local Air District:

1. Go to https://kidsmakingsense.org/curriculum/adv-aq/agencies and select your state from the drop-down menu.
2. You will now see your state's air quality agency. If your state has local districts, they will show up on the left side of the screen.
3. Some states might not have local agencies. In this case, you can use your state agency's website.
4. Search your air agency's website for "no burn day" and investigate the information your agency has available.

Inversion Layer Activity Class Demonstration

The following activity is written to be performed as a class demonstration due to the safety precautions that need to be taken when using matches and laser pointers. However, the instructions can be easily adapted for older students to perform under supervision in a laboratory setting.

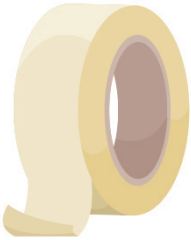
Materials Needed

1 glass container, such as a mason jar or Erlenmeyer flask, with a lid (mason jar lid, rubber stopper, or aluminum foil)

1 ice bath (optional)

1 laser pointer

matches



1 small piece of masking tape

1 ring stand and clamp (optional)

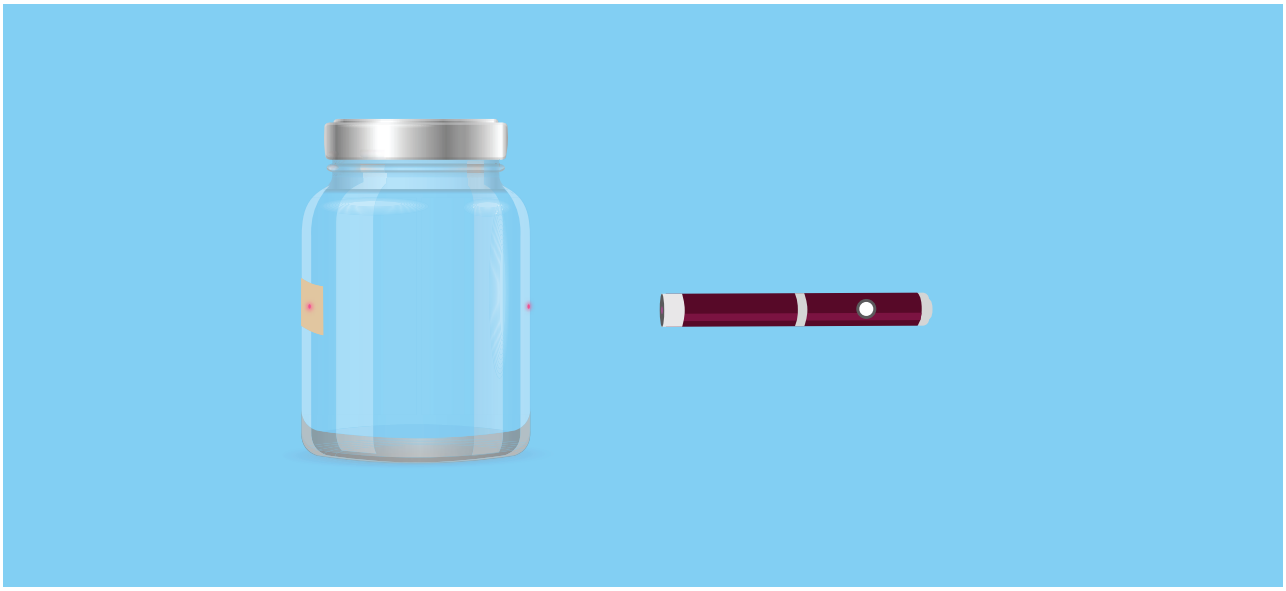
Item	Purpose
Glass container	To represent the atmosphere
Lid	Represents the warm air layer of the atmosphere
Matches	Match smoke represents wood-burning particles
Laser pointer	A way for us to visibly tell whether there is smoke present
Ring clamp	Safety
Masking tape	Safety
Ice bath	Helps to drive home the idea that the glass container is the colder air of the lower atmosphere

Experimental Setup

If you will be using a ring stand, position the ring stand so that the glass container is held securely.

1. Place a 1-inch square of masking tape on the outside of the container – this is to prevent the laser pointer's light from shining all the way through the glassware and into someone's eye. When you shine the laser pointer, be sure to aim it at the masking tape.
2. If you use an ice bath, create an ice and water mix, and place the glass container into the bath so that the water covers the bottom ~1 inch of the glass container.

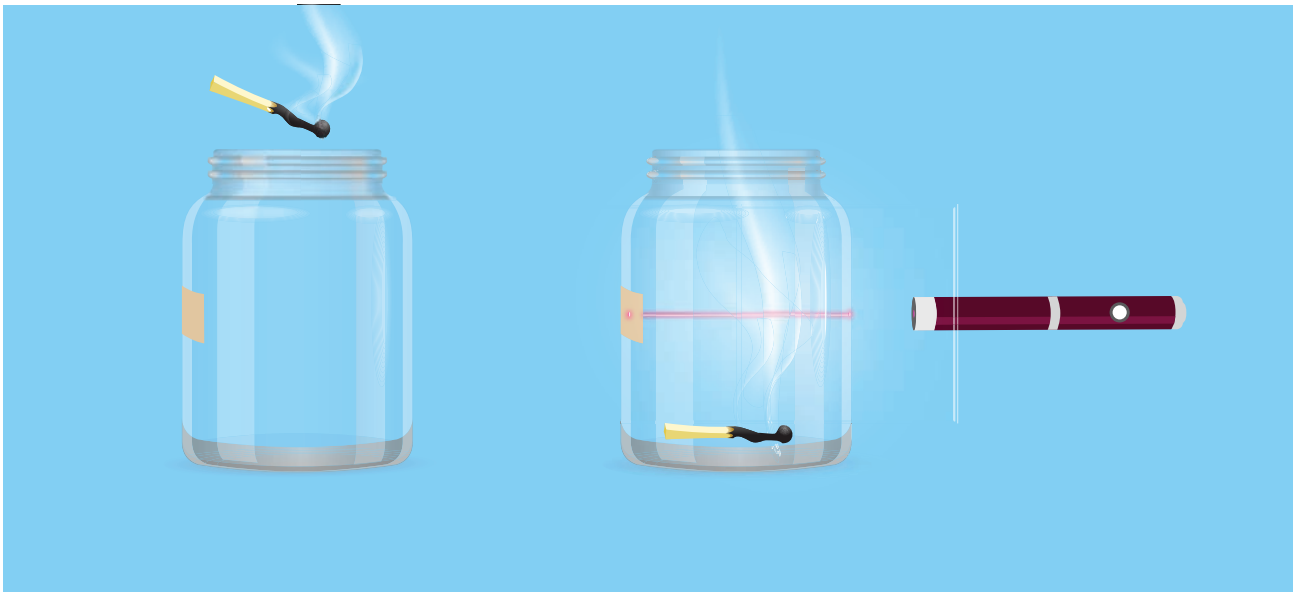
Experiment 1: Control Experiment



This experiment will help students understand how the laser beam appears normally in the absence of many particles.

1. Close the lid on your glassware and carefully shine a laser pointer through it toward the masking tape.
2. Ask students to describe their observations in their notebooks.
   Students might be able to see the laser light shining/reflecting off the side of the jar, but they won't be able to see much else inside the jar. Why is that? Similar to how air sensors work to measure particles, the laser beam's light is only visible to our eyes when it hits a surface in the air. We can see the light on the edge of the glass container because the light hits the glass wall and is scattered and reflected toward our eyes. In your classroom, there are likely very few particles in the air for the light to reflect and scatter off of, making the laser beam light invisible to our eyes.

Experiment 2: Simulate a Daytime Atmosphere



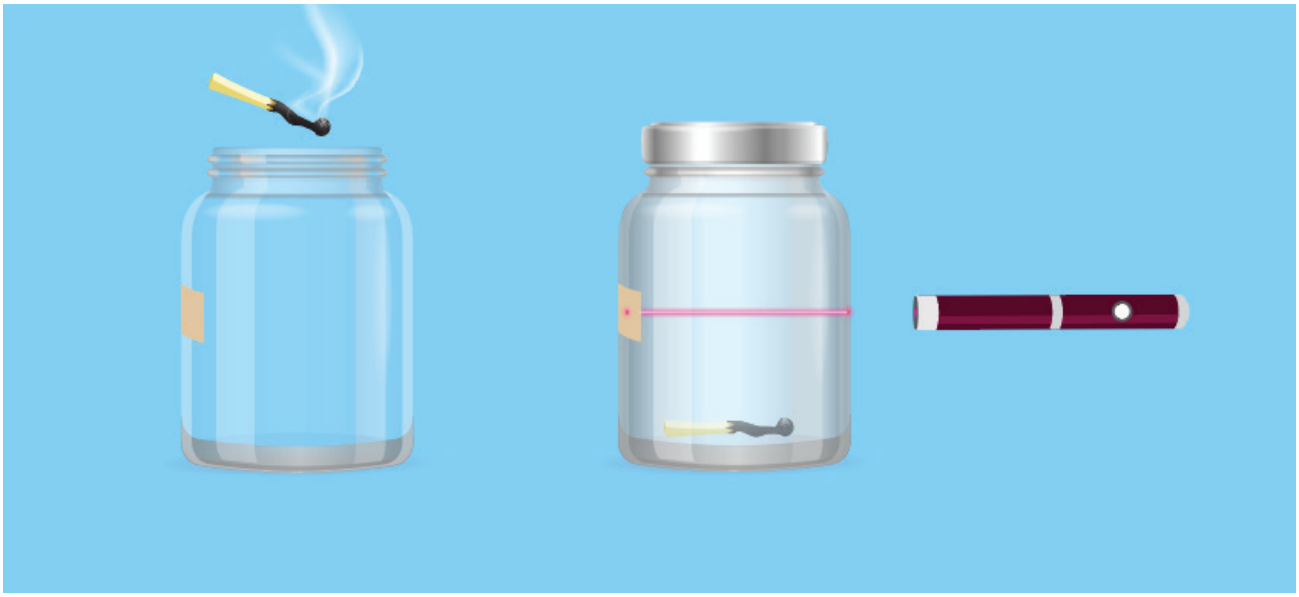
In a "normal" atmosphere, there is no warm layer of air trapping the cold air near the surface, so any smoke or air pollution is able to disperse.
In this setup:

- *The glass container represents the part of the atmosphere we live in.*
- *The smoke represents the particles produced when people burn wood during the winter.*
- *The glass container is open, so there is no warm air cap present to trap particles and they are able to dissipate into the upper atmosphere.*

1. Light a match, blow it out and put it into the glassware.
2. Do not put the lid on.
3. Shine the light through the wall of the glassware and allow students to observe.
   a. They should be able to see the light beam, as the light is now reflecting off the smoke particles in the jar.
4. Ask students to describe their observations in their notebooks.
   a. After a few minutes have passed, shine the laser light through the mason jar again. The smoke should have dissipated, so the laser beam might be much fainter or invisible again. **Ask students to describe what they see and why it might be different than what they originally saw.**

Similar to how air sensors work to measure particles, the laser beam's light is only visible to our eyes when it hits a surface in the air. We can see the light on the edge of the glass container because the light hits the glass wall and is scattered and reflected toward our eyes. In your classroom, there are likely very few particles in the air for the light to reflect and scatter off of, making the laser beam light invisible to our eyes.

Experiment 3: Simulate an Inversion Layer in the Atmosphere



Now you will simulate an inversion layer that is present in the atmosphere. As explained above, this is when a layer of warm air forms in the upper atmosphere and traps a layer of cool air below it. This happens more frequently in the wintertime, which is also when people tend to perform more burning activities to heat their homes.

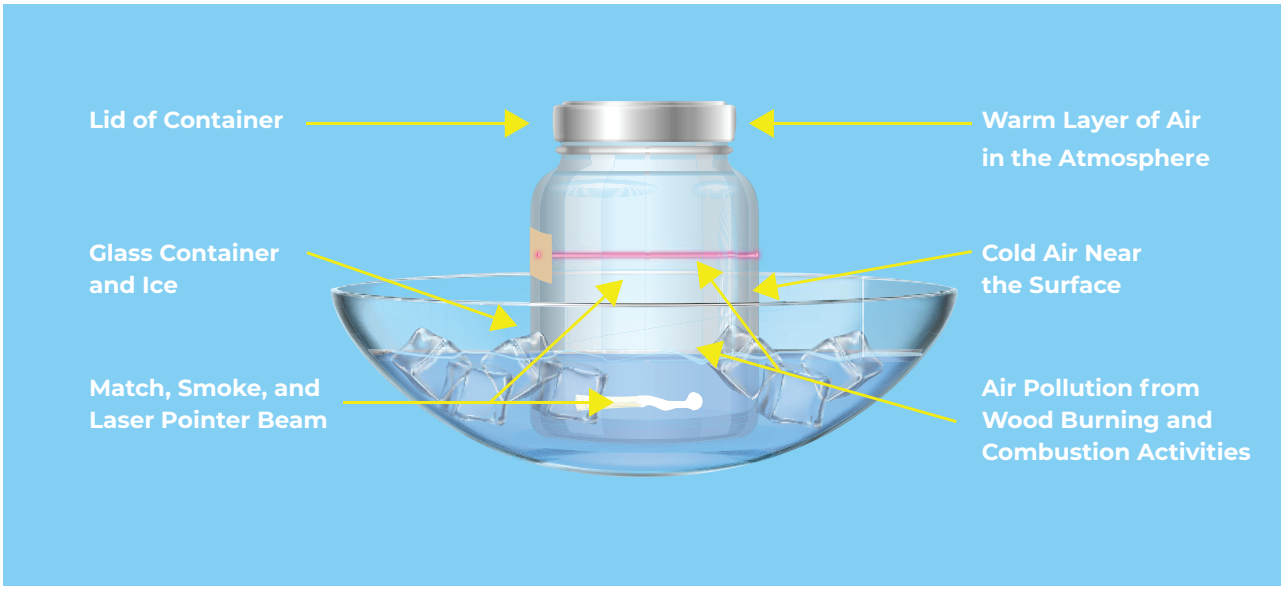
By simulating these atmospheric conditions, we will see how they impact air pollution, specifically smoke particles.

In this setup:

- *The glass container represents the part of the atmosphere we live in.*
- *The smoke represents the particles produced when people burn wood.*
- *The lid of the container represents the warm air in the atmosphere that is present above the cold air layer during a temperature inversion.*

1. Light a match and extinguish it, then place the match into the container and seal the lid.
   a. Smoke from the match should start to fill the container.
2. Carefully shine the laser through the container.
   a. The laser beam will be visible and likely very bright, as there are many particles for the laser light to scatter off of.
3. **Ask students to describe what they observe.**
4. You can repeat this process after a few minutes and you will still be able to see the laser beam well since the particles are trapped in the glass container (lower atmosphere) by the lid (warm air layer in the upper atmosphere).

Here, the lid is acting as the warm air in the atmosphere that is present during a temperature inversion. The warm air is trapping any smoke or other air pollutants near the surface - the part of the atmosphere we live in! We can tell the particles are being trapped because the laser light is scattering off the particles, making the laser light visible to our eyes. When no warm air layer (lid) was present in the "normal" atmosphere scenario, the particles dispersed after a few minutes. This is not the case when the warm air layer is present!



During inversion events, your local air district might issue a wood burn ban to try and help reduce the amount of smoke and air pollution going into the air and getting trapped! Check out your local air district website to find out more information!

Class Discussion

Possible discussion topics are listed below.

- How can we reduce our contribution to smoke in the air when an inversion layer is forecasted?
  Ideas include reducing burning activities (or if burning must occur to provide heat, burn dry wood rather than damp wood), driving less, and using public transport.
- Are there certain regions or areas that might suffer more from the effects of inversion layers because of local topography?
  Areas located in valleys are susceptible to more pronounced inversion layers. This is because cold air can sink into the low-lying areas of a valley, intensifying the phenomenon. Additionally, winds capable of mixing the warm and cold air masses and clearing out air pollutants might be limited in valley regions due to the surrounding mountains.
- How might we protect ourselves from higher levels of air pollution during inversion layer events?
  Some ideas include limiting time spent outdoors, limiting heavy exercise outdoors, and wearing an N-95 mask.

Remember, inversion layers are naturally occurring, and are not a bad thing. However, when we add pollutants to the air, the pollution that is trapped by inversion layers can create an air quality problem that could impact our health.