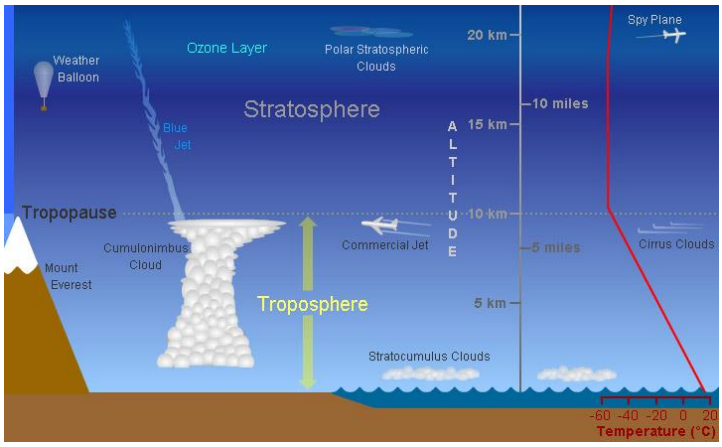
# LAYERS OF THE ATMOSPHERE

## The Troposphere

The troposphere is the lowest layer of Earth's atmosphere. The troposphere starts at Earth's surface and goes up to a height of 7 to 20 km (4 to 12 miles, or 23,000 to 65,000 feet) above sea level. Most of the mass (about 75-80%) of the atmosphere is in the troposphere. Almost all weather occurs within this layer. Air is warmest at the bottom of the troposphere near ground level. Higher up it gets colder. Air pressure and the density of the air are also less at high altitudes. The layer above the troposphere is called the stratosphere.

Nearly all of the water vapor and dust particles in the atmosphere are in the troposphere. That is why most clouds are found in this lowest layer, too. The bottom of the troposphere, right next to the surface of Earth, is called the "boundary layer". In places where Earth's surface is "bumpy" (mountains, forests) winds in the boundary layer are all jumbled up. In smooth places (over water or ice) the winds are smoother. The winds above the boundary layer aren't affected by the surface much.

The troposphere is heated from below. Sunlight warms the ground or ocean, which in turn radiates the heat into the air right above it. This warm air tends to rise. That keeps the air in the troposphere "stirred up". The top of the troposphere is quite cold. The temperature there is around -55° C (-64° F)! Air also gets 'thinner' as you go higher up. That's why mountain climbers sometimes need bottled oxygen to breathe.

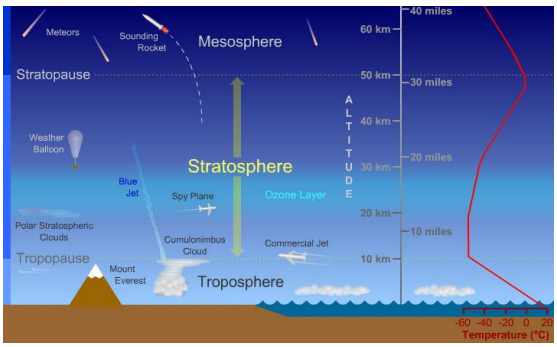



The boundary between the top of the troposphere and the stratosphere (the layer above it) is called the tropopause. The height of the tropopause depends on latitude, season, and whether it is day or night. Near the equator, the tropopause is about 20 km (12 miles or 65,000 feet) above sea level. In winter near the poles the tropopause is much lower. It is about 7 km (4 miles or 23,000 feet) high. The jet stream is just below the tropopause. This "river of air" zooms along at 400 km/hr (250 mph)!

## The Stratosphere

**The stratosphere is a layer of Earth's atmosphere. The stratosphere is the second layer, as one moves upward from Earth's surface, of the atmosphere. The stratosphere is above the troposphere and below the mesosphere.**

The top of the stratosphere occurs at 50 km (31 miles) altitude. The boundary between the stratosphere and the mesosphere above is called the stratopause. The altitude of the bottom of the stratosphere varies with latitude and with the seasons, occurring between about 8 and 16 km (5 and 10 miles, or 26,000 to 53,000 feet). The bottom of the stratosphere is around 16 km (10 miles or 53,000 feet) above Earth's surface near the equator, around 10 km (6 miles) at mid-latitudes, and around 8 km (5 miles) near the poles. It is slightly lower in winter at mid- and high-latitudes, and slightly higher in the summer. The boundary between the stratosphere and the troposphere below is called the tropopause.




Ozone, an unusual type of oxygen molecule that is relatively abundant in the stratosphere, heats this layer as it absorbs energy from incoming ultraviolet radiation from the Sun. Temperatures rise as one moves upward through the stratosphere. This is exactly the opposite of the behavior in the troposphere in which we live, where temperatures drop with increasing altitude. Because of this temperature stratification, there is little convection and mixing in the stratosphere, so the layers of air there are quite stable. Commercial jet aircraft fly in the lower stratosphere to avoid the turbulence which is common in the troposphere below.

The stratosphere is very dry; air there contains little water vapor. Because of this, few clouds are found in this layer; almost all clouds occur in the lower, more humid troposphere. Polar stratospheric clouds (PSCs) are the exception. PSCs appear in the lower stratosphere near the poles in winter. They are found at altitudes of 15 to 25 km (9.3 to 15.5 miles) and form only when temperatures at those heights dip below -78° C. They appear to help cause the formation of the infamous holes in the ozone layer by "encouraging" certain chemical reactions that destroy ozone. PSCs are also called nacreous clouds.

Air is roughly a thousand times thinner at the top of the stratosphere than it is at sea level. Because of this, jet aircraft and weather balloons reach their maximum operational altitudes within the stratosphere.

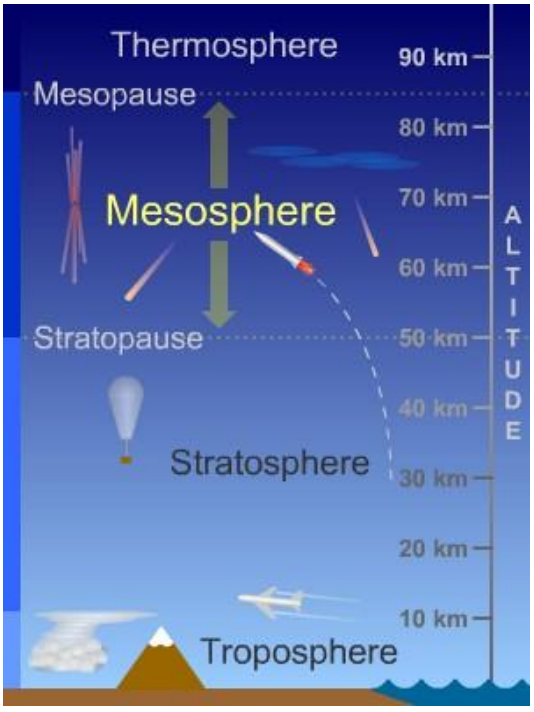
Due to the lack of vertical convection in the stratosphere, materials that get into the stratosphere can stay there for long times. Such is the case for the ozone-destroying chemicals called CFCs (chlorofluorocarbons). Large volcanic eruptions and major meteorite impacts can fling aerosol particles up into the stratosphere where they may linger for months or years, sometimes altering Earth's global climate. Rocket launches inject exhaust gases into the stratosphere, producing uncertain consequences.

## The Mesosphere

The mesosphere is a layer of Earth's atmosphere. The mesosphere is above the stratosphere layer. The layer above the mesosphere is called the thermosphere. The mesosphere starts at 50 km (31 miles) above Earth's surface and goes up to 85 km (53 miles) high.

As you get higher up in the mesosphere, the temperature gets colder. The top of the mesosphere is the coldest part of Earth's atmosphere. The temperature there is around -90° C (-130° F)!

The boundaries between layers in the atmosphere have special names. The mesopause is the boundary between the mesosphere and the thermosphere above it. The stratopause is the boundary between the mesosphere and the stratosphere below it.




Scientists know less about the mesosphere than about other layers of the atmosphere. The mesosphere is hard to study. Weather balloons and jet planes cannot fly high enough to reach the mesosphere. The orbits of satellites are above the mesosphere. We don't have many ways to get scientific instruments to the mesosphere to take measurements there. We do get some measurements using sounding rockets. Sounding rockets make short flights that don't go into orbit. Overall, there's a lot we don't know about the mesosphere because it is hard to measure and study.

What **do** we know about the mesosphere? Most meteors from space burn up in this layer. A special type of clouds, called "noctilucent clouds", sometimes forms in the mesosphere near the North and South Poles. These clouds are strange because they form much, much higher up than any other type of cloud. There are also odd types of lightning in the mesosphere. These types of lightning, called "sprites" and "ELVES", appear dozens of miles above thunderclouds in the troposphere below.

In the mesosphere and below, different kinds of gases are all mixed together in the air. Above the mesosphere, the air is so thin that atoms and molecules of gases hardly ever run into each other. The gases get separated some, depending on the kinds of elements (like nitrogen or oxygen) that are in them.

You know that waves can form in the ocean or other bodies of water. But did you know that there are waves of air in the atmosphere? Some of these waves start in the lower atmosphere, the troposphere and stratosphere, and move upward into the mesosphere. The waves carry energy to the mesosphere. Most of the movement of air in the mesosphere is caused by these waves.

## The Thermosphere

The thermosphere is a layer of Earth's atmosphere. The thermosphere is directly above the mesosphere and below the exosphere. It extends from about 90 km (56 miles) to between 500 and 1,000 km (311 to 621 miles) above our planet.

Temperatures climb sharply in the lower thermosphere (below 200 to 300 km altitude), then level off and hold fairly steady with increasing altitude above that height. Solar activity strongly influences temperature in the thermosphere. The thermosphere is typically about 200° C (360° F) hotter in the daytime than at night, and roughly 500° C (900° F) hotter when the Sun is very active than at other times. Temperatures in the upper thermosphere can range from about 500° C (932° F) to 2,000° C (3,632° F) or higher.

The boundary between the thermosphere and the exosphere above it is called the thermopause. At the bottom of the thermosphere is the mesopause, the boundary between the thermosphere and the mesosphere below.

Although the thermosphere is considered part of Earth's atmosphere, the air density is so low in this layer that most of the thermosphere is what we normally think of as outer space. In fact, the most common definition says that space begins at an altitude of 100 km (62 miles), slightly above the mesopause at the bottom of the thermosphere. The space shuttle and the International Space Station both orbit Earth within the thermosphere!

Below the thermosphere, gases made of different types of atoms and molecules are thoroughly mixed together by turbulence in the atmosphere. Air in the lower atmosphere is mainly composed of the familiar blend of about 80% nitrogen molecules ($N_2$) and about 20% oxygen molecules ($O_2$). In the thermosphere and above, gas particles collide so infrequently that the gases become somewhat separated based on the types of chemical elements they contain. Energetic ultraviolet and X-ray photons from the Sun also break apart molecules in the thermosphere. In the upper thermosphere, atomic oxygen (O), atomic nitrogen (N), and helium (He) are the main components of air.

Much of the X-ray and UV radiation from the Sun is absorbed in the thermosphere. When the Sun is very active and emitting more high energy radiation, the thermosphere gets hotter and expands or "puffs up". Because of this, the height of the top of the thermosphere (the thermopause) varies. The thermopause is found at an altitude between 500 km and 1,000 km or higher. Since many satellites orbit within the thermosphere, changes in the density of (the very, very thin) air at orbital altitudes brought on by heating and expansion of the thermosphere generates a drag force on satellites. Engineers must take this varying drag into account when calculating orbits, and satellites occasionally need to be boosted higher to offset the effects of the drag force.

Finally, the aurora (the Southern and Northern Lights) primarily occur in the thermosphere. Charged particles (electrons, protons, and other ions) from space collide with atoms and molecules in the thermosphere at high latitudes, exciting them into higher energy states. Those atoms and molecules shed this excess energy by emitting photons of light, which we see as colorful auroral displays.

**This is an image of the space shuttle as it is orbiting around the Earth. The space shuttle orbits in the thermosphere of the Earth**.

## The Exosphere

Very high up, the Earth's atmosphere becomes very thin. The region where atoms and molecules escape into space is referred to as the exosphere. The exosphere is on top of the thermosphere. The top of the exosphere marks the line between the Earth's atmosphere and interplanetary space.

The exosphere is the outermost layer of the Earth's atmosphere. It starts at an altitude of about 500 km and goes out to about 10,000 km. Within this region particles of atmosphere can travel for hundreds of kilometers in a ballistic trajectory before bumping into any other particles of the atmosphere. Particles escape out of the exosphere into deep space.

The lower boundary of the exosphere, where it interacts with the thermosphere is called the thermopause. It starts at an altitude of about 250-500 km, but its height depends on the amount of solar activity. Below the thermopause, particles of the atmosphere have atomic collisions, like what you might find in a balloon. But above the thermopause, this switches over to purely ballistic collisions. The theoretical top boundary of the exosphere is 190,000 km (half way to the Moon). This is the point at which the solar radiation coming from the Sun overcomes the Earth's gravitational pull on the atmospheric particles. This has been detected to about 100,000 km from the surface of the Earth. Most scientists consider 10,000 km to be the official boundary between the Earth's atmosphere and interplanetary space.