Atmosphere of Earth

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The **atmosphere of Earth** is a layer of gases surrounding the planet Earth that is retained by Earth's gravity. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night (the diurnal temperature variation).

Blue light is scattered more than other wavelengths by the gases in the atmosphere, giving the Earth a blue halo when seen from space onboard ISS at a height of 402–424 km.

The common name given to the atmospheric gases used in breathing and photosynthesis is **air**. By volume, dry air contains 78.09% nitrogen, 20.95% oxygen,[1] 0.93% argon, 0.039% carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapor, on average around 1%. While air content and atmospheric pressure vary at different layers, air suitable for the survival of terrestrial plants and terrestrial animals currently is only known to be found in Earth's troposphere and artificial atmospheres.

The atmosphere has a mass of about 5×10^{18} kg, three quarters of which is within about 11 km (6.8 mi; 36,000 ft) of the surface. The atmosphere becomes thinner and thinner with increasing altitude, with no definite boundary between the atmosphere and outer space. The Kármán line, at 100 km (62 mi), or 1.57% of the Earth's radius, is often used as the border between the atmosphere and outer space. Atmospheric effects become noticeable during atmospheric reentry of spacecraft at an altitude of around 120 km (75 mi). Several layers can be distinguished in the atmosphere, based on characteristics such as temperature and composition.

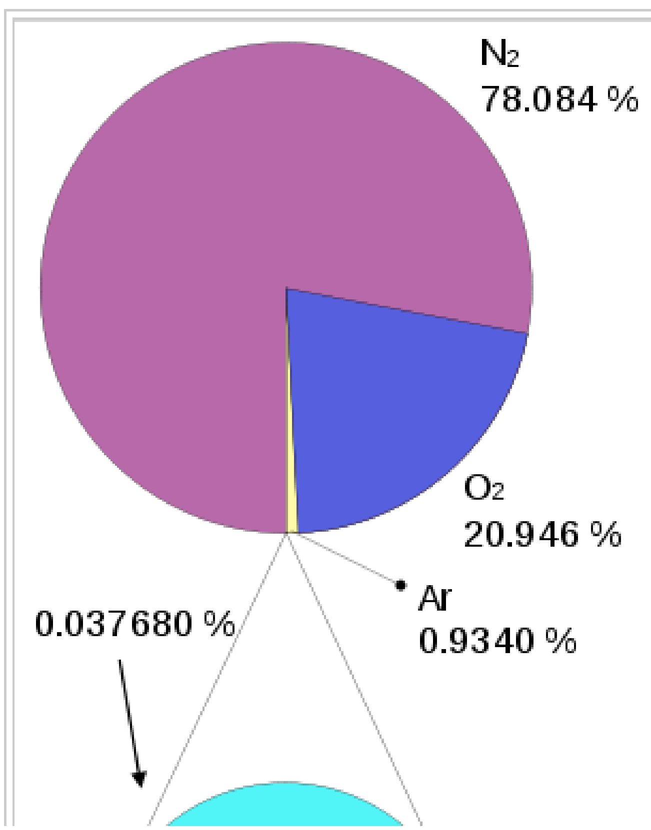
The study of Earth's atmosphere and its processes is called atmospheric science or **aerology**. Early pioneers in the field include Léon Teisserenc de Bort and Richard Assmann.[2]

Contents

Composition

Main article: Atmospheric chemistry

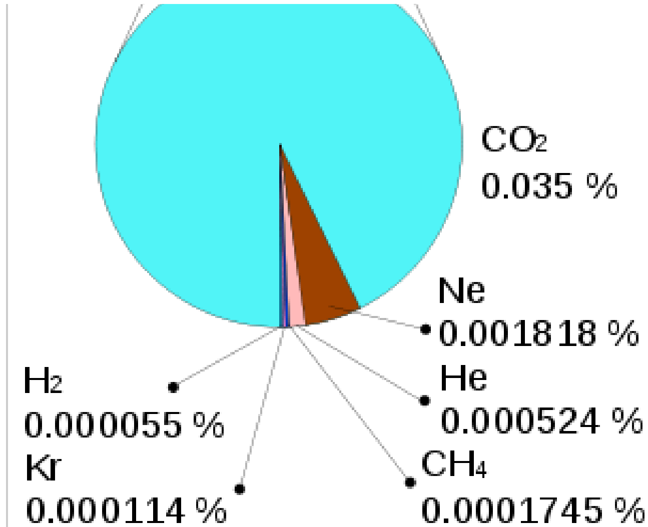
Air is mainly composed of nitrogen, oxygen, and argon, which together constitute the major gases of the atmosphere. Water vapor accounts for roughly 0.25% of the atmosphere by mass. The concentration of water vapor (a greenhouse gas) varies significantly from around 10 ppmv in the coldest portions of the atmosphere to as much as 5% by volume in hot, humid air masses, and concentrations of other atmospheric gases are typically provided for dry air without any water vapor.[3] The remaining gases are often referred to as trace gases,[4] among which are the greenhouse gases such as carbon dioxide, methane, nitrous oxide, and ozone. Filtered air includes trace amounts of many other chemical compounds. Many substances of natural origin may be present in locally and seasonally variable small amounts as aerosol in an unfiltered air sample, including dust of mineral and organic composition, pollen and spores, sea spray, and volcanic ash. Various industrial pollutants also may be present as gases or aerosol, such as chlorine (elemental or in compounds), fluorine compounds and elemental mercury vapor. Sulfur compounds such as hydrogen sulfide and sulfur dioxide (SO_2) may be derived from natural sources or from industrial air pollution.



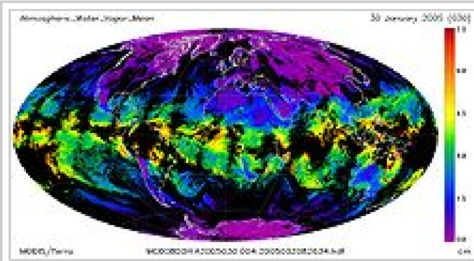
Composition of dry atmosphere, by volume[5]

ppmv: parts per million by volume (note: volume fraction is equal to mole fraction for ideal gas only, see volume (thermodynamics))

Gas	Volume
Nitrogen (N_2)	780,840 ppmv (78.084%)
Oxygen (O_2)	209,460 ppmv (20.946%)
Argon (Ar)	9,340 ppmv (0.9340%)
Carbon dioxide (CO_2)	397 ppmv (0.0397%)
Neon (Ne)	18.18 ppmv (0.001818%)
Helium (He)	5.24 ppmv (0.000524%)
Methane (CH_4)	1.79 ppmv (0.000179%)
Krypton (Kr)	1.14 ppmv (0.000114%)
Hydrogen (H_2)	0.55 ppmv (0.000055%)
Nitrous oxide (N_2O)	0.325 ppmv (0.0000325%)
Carbon monoxide (CO)	0.1 ppmv (0.00001%)
Xenon (Xe)	0.09 ppmv (9×10^{-6}%) (0.000009%)
Ozone (O_3)	0.0 to 0.07 ppmv (0 to 7×10^{-6}%)
Nitrogen dioxide (NO_2)	0.02 ppmv (2×10^{-6}%) (0.000002%)
Iodine (I_2)	0.01 ppmv (1×10^{-6}%) (0.000001%)
Ammonia (NH_3)	trace
Not included in above dry atmosphere:	
Water vapor (H_2O)	~0.25% by mass over full atmosphere, locally 0.001%–5% [3]



Composition of Earth's atmosphere by volume. The lower pie represents the trace gases which together compose 0.038% of the atmosphere. The numbers are from a variety of years (mainly 1987, with CO_2 and methane from 2009) and do not represent any single source.



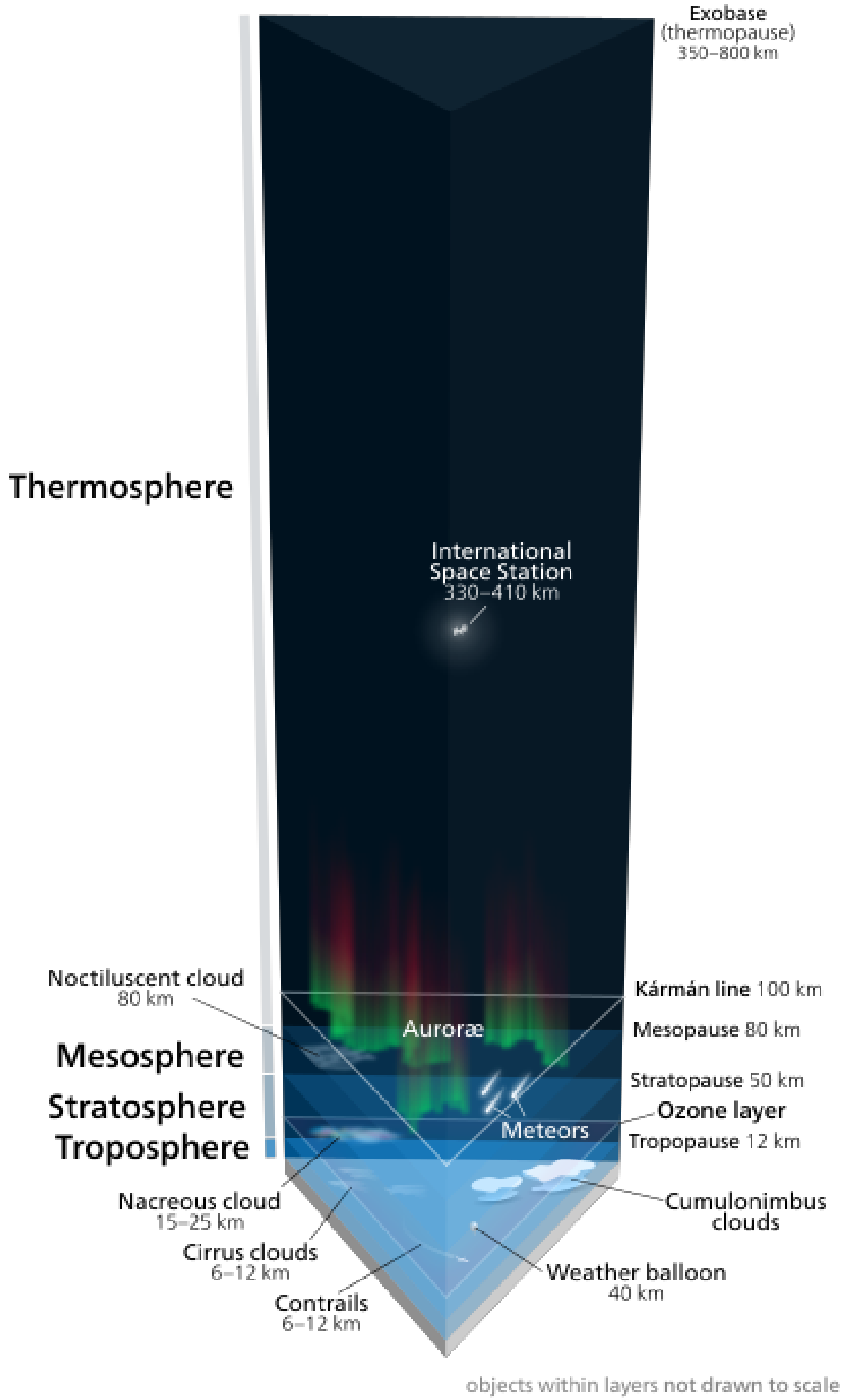
Mean atmospheric water vapor

Structure of the atmosphere

Principal layers

In general, air pressure and density decrease with altitude in the atmosphere. However, temperature has a more complicated profile with altitude, and may remain relatively constant or even increase with altitude in some regions (see the temperature section, below). Because the general pattern of the temperature/altitude profile is constant and recognizable through means such as balloon soundings, the temperature behavior provides a useful metric to distinguish between atmospheric layers. In this way, Earth's atmosphere can be divided (called atmospheric stratification) into five main layers. From highest to lowest, these layers are:

▼ **Earth's atmosphere** Layers of the atmosphere drawn to scale, objects within the layers are not to scale.



Exosphere

Main article: Exosphere

The exosphere is the outermost layer of Earth's atmosphere, ranging from the exobase at an altitude of about 700 km. above sea level to about half way to the Moon. It is mainly composed of hydrogen, helium and some heavier molecules such as nitrogen, oxygen and carbon dioxide closer to the exobase. The atoms and molecules are so far apart that they can travel hundreds of kilometers without colliding with one another, so the atmosphere no longer behaves like a gas. These free-moving particles follow ballistic trajectories and may migrate in and out of the magnetosphere or the solar wind.

Thermosphere

Main article: Thermosphere

Temperature increases with height in the thermosphere from the mesopause at an altitude of about 80 km (50 mi; 260,000 ft) up to the thermopause, then is constant with height entering the exosphere. Since the thermopause is at the bottom of the exosphere, it also called the exobase. Its height averages about 700 km above Earth but actually varies with solar activity and ranges from about 500–1,000 km (310–620 mi; 1,600,000 – 3,300,000 ft).[6] Unlike the stratosphere, where a temperature inversion is caused by absorption of radiation by ozone, the inversion in the thermosphere is a result of the extremely low density of molecules. The temperature of this layer can rise to 1,500 °C (2,700 °F), though the gas molecules are so far apart that temperature in the usual sense is not well defined. The air is so rarefied that an individual molecule (of oxygen, for example) travels an average of 1 kilometer between collisions with other molecules.[7] The International Space Station orbits in this layer, between 320 and 380 km (200 and 240 mi). The aurora borealis and aurora australis are occasionally seen in the thermosphere and the lower part of the exosphere.

Mesosphere

Main article: Mesosphere

The mesosphere extends from the stratopause at an altitude of about 50 km (31 mi; 160,000 ft) to the mesopause at 80–85 km (50–53 mi; 260,000–280,000 ft) above sea level. It is the layer where most meteors burn up upon entering the atmosphere. Temperature decreases with height in the mesosphere. The mesopause, the temperature minimum that marks the top of the mesosphere, is the coldest place on Earth and has an average temperature around −85 °C (−120 °F; 190 K).[8] At this altitude, temperatures may drop to −100 °C (−150 °F; 170 K).[9] Due to the cold temperature of this layer, water vapor is frozen, occasionally forming polar-mesospheric noctilucent clouds which are the highest water-based aerosols in the atmosphere. A type of lightning referred to as either sprites or ELVES, occasionally form far above tropospheric thunderclouds.

Stratosphere

Main article: Stratosphere

The stratosphere ranges from the tropopause at about 12 km (7.5 mi; 39,000 ft) above Earth to the stratopause at an altitude of 50 to 55 km (31 to 34 mi; 160,000 to 180,000 ft). The atmospheric pressure at the top of the stratosphere is roughly 1/1000 the pressure at sea level. Temperature increases with height due to increased absorption of ultraviolet radiation by the ozone layer, which restricts turbulence and mixing. While the temperature may be −60 °C (−76 °F; 210 K) at the tropopause, the top of the stratosphere is much warmer, and may be near freezing.[10] Polar stratospheric or nacreous clouds are occasionally seen in this layer of the atmosphere.

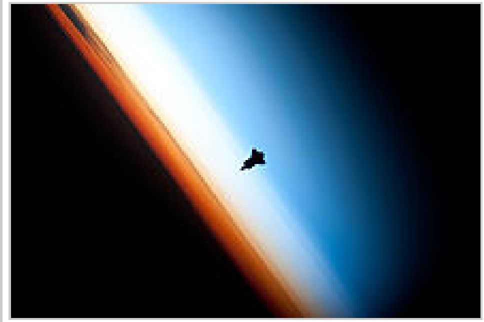
Troposphere

Main article: Troposphere

The troposphere begins at Earth's surface and extends to the tropopause at an average height of about 12 km, although this altitude actually varies from about 9 km (30,000 ft) at the poles and 17 km (56,000 ft) at the equator,[11] with some variation due to weather. The troposphere is mostly heated by transfer of energy from the surface, so on average the lowest part of the troposphere is warmest and temperature decreases with altitude. This promotes vertical mixing (hence the origin of its name in the Greek word τρόπος, *tropos*, meaning "turn"). The troposphere contains roughly 80% of the mass of the atmosphere and basically all the weather-associated cloud genus types (very tall cumulonimbus thunder clouds can penetrate the stratosphere from below).[12] The tropopause is the boundary between the troposphere and stratosphere.

Other layers

Within the five principal layers which are largely determined by temperature, several secondary layers may be distinguished by other properties:



Space Shuttle *Endeavour* appearing to straddle the stratosphere and mesosphere. The orange layer is the troposphere, which gives way to the whitish stratosphere and then the blue mesosphere.[13]

- The ozone layer is contained within the stratosphere. In this layer ozone concentrations are about 2 to 8 parts per million, which is much higher than in the lower atmosphere but still very small compared to the main components of the atmosphere. It is mainly located in the lower portion of the stratosphere from about 15–35 km (9.3–22 mi; 49,000–110,000 ft), though the thickness varies seasonally and geographically. About 90% of the ozone in our atmosphere is contained in the stratosphere.
- The ionosphere is a region of the atmosphere that is ionized by solar radiation. It is responsible for auroras. During daytime hours, it stretches from 50 to 1,000 km (31 to 620 mi; 160,000 to 3,300,000 ft) and includes the mesosphere, thermosphere, and parts of the exosphere. However, ionization in the mesosphere largely ceases during the night, so auroras are normally seen only in the themosphere and lower exosphere. The ionosphere forms the inner edge of the magnetosphere. It has practical importance because it influences, for example, radio propagation on Earth.
- The homosphere and heterosphere are defined by whether the atmospheric gases are well mixed. The surfaced-based homosphere includes the troposphere, stratosphere, mesosphere, and the lowest part of the thermosphere, where the chemical composition of the atmosphere does not depend on molecular weight because the gases are mixed by turbulence.[14] This relatively homogeneous layer ends at the *turbopause* which is found at about 100 km (62 mi; 330,000 ft), which places it about 20 km (12 mi; 66,000 ft) above the mesopause.

  Above this altitude lies the heterosphere which includes the exosphere and most of the themosphere. Here the chemical composition varies with altitude. This is because the distance that particles can move without colliding with one another is large compared with the size of motions that cause mixing. This allows the gases to stratify by molecular weight, with the heavier ones such as oxygen and nitrogen present only near the bottom of the heterosphere. The upper part of the heterosphere is composed almost completely of hydrogen, the lightest element.

- The planetary boundary layer is the part of the troposphere that is closest to Earth's surface and is directly affected by it, mainly through turbulent diffusion. During the day the planetary boundary layer usually is well-mixed, whereas at night it becomes stably stratified with weak or intermittent mixing. The depth of the planetary boundary layer ranges from as little as about 100 meters on clear, calm nights to 3000 m or more during the afternoon in dry regions.

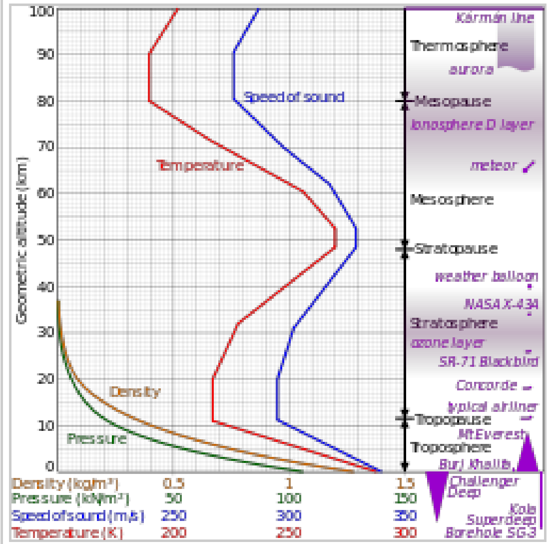
The average temperature of the atmosphere at the surface of Earth is 14 °C (57 °F; 287 K)[15] or 15 °C (59 °F; 288 K),[16] depending on the reference.[17][18][19]

Physical properties

Pressure and thickness

Main article: Atmospheric pressure

The average atmospheric pressure at sea level is 1 standard atmosphere (atm)=101.3 kPa (kilopascals)=14.7 psi (pounds per square inch)=760 torr=29.92 inches of mercury (symbol Hg). Total atmospheric mass is 5.1480×10^{18} kg (1.135×10^{19} lb),[21] about 2.5% less than would be inferred from the average sea level pressure and the Earth's area of 51007.2 megahectares, this portion being displaced by the Earth's mountainous terrain. Atmospheric pressure is the total weight of the air above unit area at the point where the pressure is measured. Thus air pressure varies with location and weather.



Comparison of the 1962 US Standard Atmosphere graph of geometric altitude against air density, pressure, the speed of sound and temperature with approximate altitudes of various objects.[20]

If the atmosphere had a uniform density, it would terminate abruptly at an altitude of 8.50 km (27,900 ft). It actually decreases exponentially with altitude, dropping by half every 5.6 km (18,000 ft) or by a factor of 1/e every 7.64 km (25,100 ft), the average scale height of the atmosphere below 70 km (43 mi; 230,000 ft). However, the atmosphere is more accurately modeled with a customized equation for each layer that takes gradients of temperature, molecular composition, solar radiation and gravity into account.

In summary, the mass of Earth's atmosphere is distributed approximately as follows:[22]

- 50% is below 5.6 km (18,000 ft).
- 90% is below 16 km (52,000 ft).
- 99.99997% is below 100 km (62 mi; 330,000 ft), the Kármán line. By international convention, this marks the beginning of space where human travelers are considered astronauts.

By comparison, the summit of Mt. Everest is at 8,848 m (29,029 ft); commercial airliners typically cruise between 10 km (33,000 ft) and 13 km (43,000 ft) where the thinner air improves fuel economy; weather balloons reach 30.4 km (100,000 ft) and above; and the highest X-15 flight in 1963 reached 108.0 km (354,300 ft).

Even above the Kármán line, significant atmospheric effects such as auroras still occur. Meteors begin to glow in this region though the larger ones may not burn up until they penetrate more deeply. The various layers of Earth's ionosphere, important to HF radio propagation, begin below 100 km and extend beyond 500 km. By comparison, the International Space Station and Space Shuttle typically orbit at 350–400 km, within the F-layer of the ionosphere where they encounter enough atmospheric drag to require reboosts every few months. Depending on solar activity, satellites can experience noticeable atmospheric drag at altitudes as high as 700–800 km.

Temperature and speed of sound

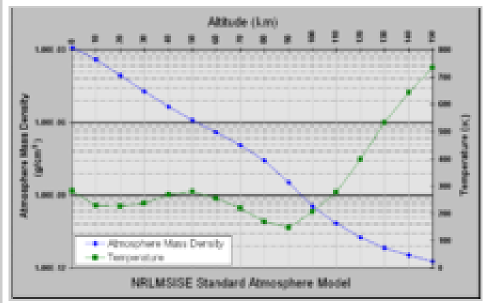
Main articles: Atmospheric temperature and Speed of sound

The division of the atmosphere into layers mostly by reference to temperature is discussed above. Temperature decreases with altitude starting at sea level, but variations in this trend begin above 11 km, where the temperature stabilizes through a large vertical distance through the rest of the troposphere. In the stratosphere, starting above about 20 km, the temperature increases with height, due to heating within the ozone layer caused by capture of significant ultraviolet radiation from the Sun by the dioxygen and ozone gas in this region. Still another region of increasing temperature with altitude occurs at very high altitudes, in the aptly-named thermosphere above 90 km.

Because in an ideal gas of constant composition the speed of sound depends only on temperature and not on the gas pressure or density, the speed of sound in the atmosphere with altitude takes on the form of the complicated temperature profile (see illustration to the right), and does not mirror altitudinal changes in density or pressure.

Density and mass

Main article: Density of air



Temperature and mass density against altitude from the NRLMSISE-00 standard atmosphere model (the eight dotted lines in each "decade" are at the eight cubes 8, 27, 64, ..., 729)

The density of air at sea level is about 1.2 kg/m^3 (1.2 g/L). Density is not measured directly but is calculated from measurements of temperature, pressure and humidity using the equation of state for air (a form of the ideal gas law). Atmospheric density decreases as the altitude increases. This variation can be approximately modeled using the barometric formula. More sophisticated models are used to predict orbital decay of satellites.

The average mass of the atmosphere is about 5 quadrillion (5×10^{15}) tonnes or 1/1,200,000 the mass of Earth. According to the American National Center for Atmospheric Research, "The total mean mass of the atmosphere is 5.1480×10^{18} kg with an annual range due to water vapor of 1.2 or 1.5×10^{15} kg depending on whether surface pressure or water vapor data are used; somewhat smaller than the previous estimate. The mean mass of water vapor is estimated as 1.27×10^{16} kg and the dry air mass as $5.1352 \pm 0.0003 \times 10^{18}$ kg."

Optical properties

See also: Sunlight

Solar radiation (or sunlight) is the energy the Earth receives from the Sun. The Earth also emits radiation back into space, but at longer wavelengths that we cannot see. Part of the incoming and emitted radiation is absorbed or reflected by the atmosphere.

Scattering

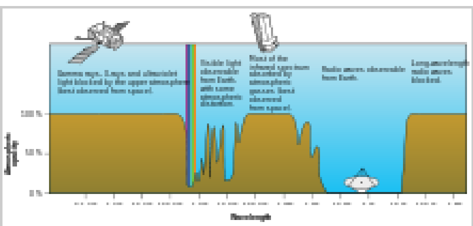
Main article: Scattering

When light passes through our atm ... If the light does not interact with the atmosphere, it is called *di* ... k directly at the Sun. *Indirect radiation* is light that has ... overcast day when you cannot see your shadow there is n ... ed. As another example, due to a phenomenon called Rayle ... re easily than longer (red) wavelengths. This is why the sky looks blue; you are seeing scattered blue light. This is also why sunsets are red. Because the Sun is close to the horizon, the Sun's rays pass through more atmosphere than normal to reach your eye. Much of the blue light has been scattered out, leaving the red light in a sunset.

Absorption

Main article: Absorption (electromagnetic radiation)

Different molecules absorb different wavelengths of radiation. For example, O_2 and O_3 absorb almost all wavelengths shorter than 300 nanometers. Water (H_2O) absorbs many wavelengths above 700 nm. When a molecule absorbs a photon, it increases the energy of the molecule. We can think of this as heating the atmosphere, but the atmosphere also cools by emitting radiation, as discussed below.



Rough plot of Earth's atmospheric transmittance (or opacity) to various wavelengths of electromagnetic radiation, including visible light.

The combined absorption spectra of the gases in the atmosphere leave "windows" of low opacity, allowing the transmission of only certain bands of light. The optical window runs from around 300 nm (ultraviolet-C) up into the range humans can see, the visible spectrum (commonly called light), at roughly 400–700 nm and continues to the infrared to around 1100 nm. There are also infrared and radio windows that transmit some infrared and radio waves at longer wavelengths. For example, the radio window runs from about one centimeter to about eleven-meter waves.

Emission

Main article: Emission (electromagnetic radiation)

Emission is the opposite of absorption, it is when an object emits radiation. Objects tend to emit amounts and wavelengths of radiation depending on their "black body" emission curves, therefore hotter objects tend to emit more radiation, with shorter wavelengths. Colder objects emit less radiation, with longer wavelengths. For example, the Sun is approximately 6,000 K (5,730 °C; 10,340 °F), its radiation peaks near 500 nm, and is visible to the human eye. The Earth is approximately 290 K (17 °C; 62 °F), so its radiation peaks near 10,000 nm, and is much too long to be visible to humans.

Because of its temperature, the atmosphere emits infrared radiation. For example, on clear nights the Earth's surface cools down faster than on cloudy nights. This is because clouds (H_2O) are strong absorbers and emitters of infrared radiation. This is also why it becomes colder at night at higher elevations.

The greenhouse effect is directly related to this absorption and emission effect. Some gases in the atmosphere absorb and emit infrared radiation, but do not interact with sunlight in the visible spectrum. Common examples of these are CO_2 and H_2O.

Refractive index

The refractive index of air is close to, but just greater than 1. Systematic variations in refractive index can lead to the bending of light rays over long optical paths. One example is that, under some circumstances, observers onboard ships can see other vessels just over the horizon because light is refracted in the same direction as the curvature of the Earth's surface.

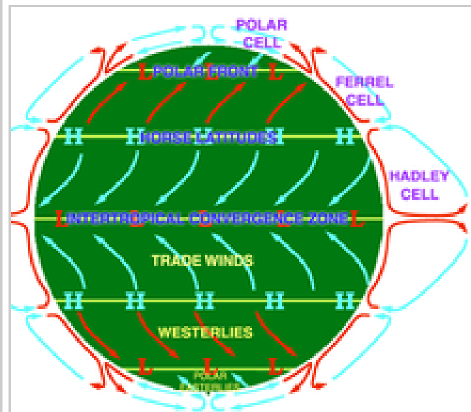
The refractive index of air depends on temperature, giving rise to refraction effects when the temperature gradient is large. An example of such effects is the mirage.

See also: Scintillation (astronomy)

Circulation

Main article: Atmospheric circulation

Atmospheric circulation is the large-scale movement of air through the troposphere, and the means (with ocean circulation) by which heat is distributed around the Earth. The large-scale structure of the atmospheric circulation varies from year to year, but the basic structure remains fairly constant as it is determined by the Earth's rotation rate and the difference in solar radiation between the equator and poles.



An idealised view of three large circulation cells.

Evolution of Earth's atmosphere

See also: History of Earth and Paleoclimatology

Earliest atmosphere

The first atmosphere would have consisted of gases in the solar nebula, primarily hydrogen. In addition there would probably have been simple hydrides such as are now found in gas-giant planets like Jupiter and Saturn, notably water vapor, methane and ammonia. As the solar nebula dissipated these gases would have escaped, partly driven off by the solar wind.[23]

Second atmosphere

The next atmosphere, consisting largely of nitrogen plus carbon dioxide and inert gases, was produced by outgassing from volcanism, supplemented by gases produced during the late heavy bombardment of Earth by huge asteroids.[23] A major part of carbon dioxide emissions were soon dissolved in water and built up carbonate sediments.

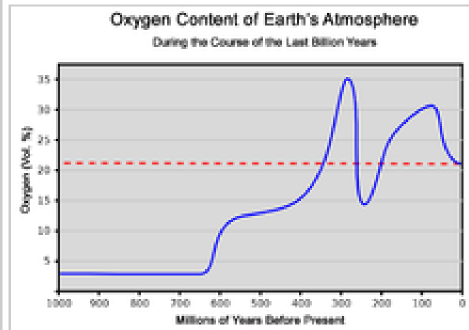
Water-related sediments have been found dating from as early as 3.8 billion years ago.[24] About 3.4 billion years ago, nitrogen was the major part of the then stable "second atmosphere". An influence of life has to be taken into account rather soon in the history of the atmosphere, since hints of early life forms are to be found as early as 3.5

billion years ago.[25] The fact that this is not perfectly in line with the 30% lower solar radiance (compared to today) of the early Sun has been described as the "faint young Sun paradox".

The geological record however shows a continually relatively warm surface during the complete early temperature record of the Earth with the exception of one cold glacial phase about 2.4 billion years ago. In the late Archaean eon an oxygen-containing atmosphere began to develop, apparently from photosynthesizing cyanobacteria (see Great Oxygenation Event) which have been found as stromatolite fossils from 2.7 billion years ago. The early basic carbon isotopy (isotope ratio proportions) is very much in line with what is found today,[26] suggesting that the fundamental features of the carbon cycle were established as early as 4 billion years ago.

Third atmosphere

The constant re-arrangement of continents by plate tectonics influences the long-term evolution of the atmosphere by transferring carbon dioxide to and from large continental carbonate stores.[27] Free oxygen did not exist in the atmosphere until about 2.4 billion years ago during the Great Oxygenation Event and its appearance is indicated by the end of the banded iron formations. Before this time, any oxygen produced by photosynthesis was consumed by oxidation of reduced materials, notably iron. Molecules of free oxygen did not start to accumulate in the atmosphere until the rate of production of oxygen began to exceed the availability of reducing materials. This point signifies a shift from a reducing atmosphere to an oxidizing atmosphere. O_2 showed major variations until reaching a steady state of more than 15% by the end of the Precambrian.[28] The following time span was the Phanerozoic eon, during which oxygen-breathing metazoan life forms began to appear.



Oxygen content of the atmosphere over the last billion years. This diagram in more detail (http://www.nap.edu/openbook/0309100615/gifmid/30.gif)

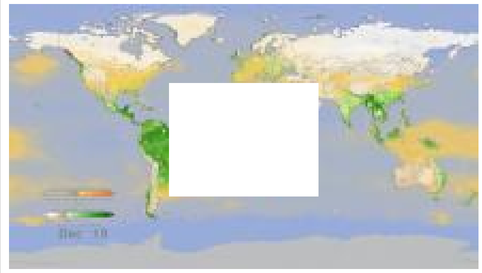
The amount of oxygen in the atmosphere has fluctuated over the last 600 million years, reaching a peak of about 30% around 280 million years ago, significantly higher than today's 21%. Two main processes govern changes in the atmosphere: Plants use carbon dioxide from the atmosphere, releasing oxygen. Breakdown of pyrite and volcanic eruptions release sulfur into the atmosphere, which oxidizes and hence reduces the amount of oxygen in the atmosphere. However, volcanic eruptions also release carbon dioxide, which plants can convert to oxygen. The exact cause of the variation of the amount of oxygen in the atmosphere is not known. Periods with much oxygen in the atmosphere are associated with rapid development of animals. Today's atmosphere contains 21% oxygen, which is high enough for this rapid development of animals.[29]

Currently, anthropogenic greenhouse gases are accumulating in the atmosphere, which is the main cause of global warming.[30]

Air pollution

Main article: Air pollution

Air pollution is the introduction into the atmosphere of chemicals, particulate matter, or biological materials that cause harm or discomfort to organisms.[31] Stratospheric ozone depletion is believed to be caused by air pollution (chiefly from chlorofluorocarbons).



This animation shows the buildup of tropospheric CO_2 in the Northern Hemisphere with a maximum around May. The maximum in the vegetation cycle follows, occurring in the late summer. Following the peak in vegetation, the drawdown of atmospheric CO_2 due to photosynthesis is apparent, particularly over the boreal forests.

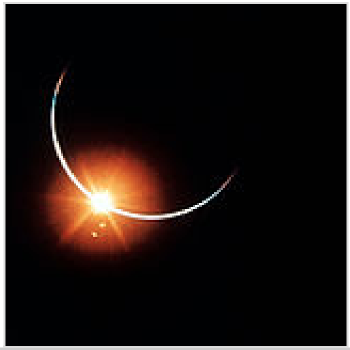
Images from space

Blue light is scattered more than other wavelengths by the gases in the atmosphere, giving the

The geomagnetic storms cause beautiful displays of aurora across the atmosphere.

Limb view, of the Earth's atmosphere. Colours roughly denote the layers of the atmosphere.

This image shows the moon at centre, with the limb of Earth near the bottom transitioning into the orange-



Earth's atmosphere backlit by the Sun in an eclipse observed from deep space onboard Apollo 12 in 1969.

See also

- Aerial perspective
- Air (classical element)
- Air glow
- Airshed
- Atmosphere (for information on atmospheres in general)
- Atmospheric dispersion modeling
- Atmospheric electricity
- Atmospheric models
- Atmospheric Radiation Measurement (ARM) (in the U.S.)
- Atmospheric stratification
- Aviation
- Biosphere
- Carbon dioxide in Earth's atmosphere
- Compressed air
- Environmental impact of aviation
- Global dimming
- Historical temperature record
- Hydrosphere
- Hypermobility (travel)
- Kyoto Protocol
- Leaching (agriculture)
- Lithosphere
- Standard Dry Air
- COSPAR international reference atmosphere (CIRA)
- U.S. Standard Atmosphere
- Warm period
- Water vapor in Earth's atmosphere

References

1. ^ Zimmer, Carl (3 October 2013). "Earth's Oxygen: A Mystery Easy to Take for Granted" (http://www.nytimes.com/2013/10/03/science/earths-oxygen-a-mystery-easy-to-take-for-granted.html). *New York Times*. Retrieved 3 October 2013.
2. ^ [1] (http://books.google.com/books?id=OlckxY7BA_0C&pg=PA17&lpg=PA17&dq=Assman+stratosphere&source=bl&ots=YN13AEOnkN&sig=zwpdSVh0OW6UUToQoFzETgIudUc&hl=en&ei=H9feTuOkCYiQiAL4qfHPCA&sa=X&oi=book_result&ct=result&resnum=6&sqi=2&ved=0CEwQ6AEwBQ#v=onepage&q=Assman%20stratosphere&f=false) Ultraviolet radiation in the solar system By Manuel Vázquez, Arnold Hanslmeier
3. ^ *a b* Wallace, John M. and Peter V. Hobbs. Atmospheric Science; *An Introductory Survey*.Elsevier. Second Edition, 2006. ISBN 13:978-0-12-732951-2. Chapter 1
4. ^ "Trace Gases" (http://www.ace.mmu.ac.uk/eae/Atmosphere/Older/Trace_Gases.html). Ace.mmu.ac.uk. Archived (http://web.archive.org/web/20101009044345/http://www.ace.mmu.ac.uk/eae/atmosphere/older/Trace_Gases.html) from the original on 9 October 2010. Retrieved 2010-10-16.
5. ^ Source for figures: Carbon dioxide, NOAA Earth System Research Laboratory (http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo), (updated 2013-03). Methane, IPCC TAR table 6.1 (http://www.grida.no/climate/ipcc_tar/wg1/221.htm#tab61), (updated to 1998). The NASA total was 17 ppmv over 100%, and CO_2 was increased here by 15 ppmv. To normalize, N_2 should be reduced by about 25 ppmv and O_2 by about 7 ppmv.
6. ^ Randy Russell (2008). "The Thermosphere" (http://www.windows2universe.org/earth/Atmosphere/thermosphere.html). Retrieved 2013-10-18.
7. ^ Ahrens, C. Donald. Essentials of Meteorology. Published by Thomson Brooks/Cole, 2005.
8. ^ States, Robert J.; Gardner, Chester S. (January 2000). "Thermal Structure of the Mesopause Region (80–105 km) at 40°N Latitude. Part I: Seasonal Variations". *Journal of the Atmospheric Sciences 2000* **57**: 66–77. Bibcode:2000JAtS...57...66S (http://adsabs.harvard.edu/abs/2000JAtS...57...66S). doi:10.1175/1520-0469(2000)057<0066:TSOTMR>2.0.CO;2 (http://dx.doi.org/10.1175%2F1520-0469%282000%29057%3C0066%3ATSOTMR%3E2.0.CO%3B2).
9. ^ Joe Buchdahl. "Atmosphere, Climate & Environment Information Programme" (http://www.ace.mmu.ac.uk/eae/Atmosphere/Older/Mesosphere.html). Ace.mmu.ac.uk. Retrieved 2012-04-18.
10. ^ Journal of the Atmospheric Sciences (1993). "stratopause" (http://www.webref.org/chemistry/s/stratopause.htm). Retrieved 2013-10-18.
11. ^ "The height of the tropopause" (http://www-das.uwyo.edu/~geerts/cwx/notes/chap01/tropo.html). Das.uwyo.edu. Retrieved 2012-04-18.
12. ^ McGraw-Hill Concise Encyclopedia of Science & Technology. (1984). Troposhere. "It contains about four-fifths of the mass of the whole atmosphere."
13. ^ "ISS022-E-062672 caption" (http://spaceflight.nasa.gov/gallery/images/shuttle/sts-130/html/iss022e062672.html). NASA. Retrieved 21 September 2012.
14. ^ ""homosphere"—AMS Glossary" (http://amsglossary.allenpress.com/glossary/search?id=homosphere1). Amsglossary.allenpress.com. Archived (http://web.archive.org/web/20100914045832/http://amsglossary.allenpress.com/glossary/search?id=homosphere1) from the original on 14 September 2010. Retrieved 2010-10-16.
15. ^ "Earth's Atmosphere" (http://www.bambooweb.com/articles/e/a/Earth's_atmosphere.html).
16. ^ "NASA — Earth Fact Sheet" (http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html). Nssdc.gsfc.nasa.gov. Archived (http://web.archive.org/web/20101030234253/http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html) from the original on 30 October 2010. Retrieved 2010-10-16.
17. ^ "Global Surface Temperature Anomalies" (http://www.ncdc.noaa.gov/oa/climate/research/anomalies/index.php).
18. ^ "Earth's Radiation Balance and Oceanic Heat Fluxes" (http://oceanworld.tamu.edu/resources/oceanography-book/radiationbalance.htm).
19. ^ "Coupled Model Intercomparison Project Control Run" (http://www-

pcmdi.llnl.gov/projects/cmip/overview_ms/control_tseries.pdf).
20. ^ Geometric altitude vs. temperature, pressure, density, and the speed of sound derived from the 1962 U.S. Standard Atmosphere. (http://www.centennialofflight.gov/essay/Theories_of_Flight/atmosphere/TH1G1.htm)
21. ^ "The Mass of the Atmosphere: A Constraint on Global Analyses" (http://ams.allenpress.com/perlserv/?request=get-abstract&doi=10.1175%2FJCLI-3299.1). Ams.allenpress.com. 1970-01-01. Retrieved 2010-10-16.
22. ^ Lutgens, Frederick K. and Edward J. Tarbuck (1995) *The Atmosphere*, Prentice Hall, 6th ed., pp14-17, ISBN 0-13-350612-6
23. ^ *a b* Zahnle, K.; Schaefer, L.; Fegley, B. (2010). "Earth's Earliest Atmospheres". *Cold Spring Harbor Perspectives in Biology* **2** (10): a004895. doi:10.1101/cshperspect.a004895 (http://dx.doi.org/10.1101%2Fcshperspect.a004895). PMID 20573713 (//www.ncbi.nlm.nih.gov/pubmed/20573713).
24. ^ B. Windley: *The Evolving Continents*. Wiley Press, New York 1984
25. ^ J. Schopf: *Earth's Earliest Biosphere: Its Origin and Evolution*. Princeton University Press, Princeton, N.J., 1983
26. ^ Celestial climate driver: a perspective from 4 billion years of the carbon cycle Geoscience Canada, March, 2005 by Jan Veizer
27. ^ Veizer in B. F. Windley (ed.), The Early History of the Earth, John Wiley and Sons, London, p. 569., 1976
28. ^ Christopher R. Scotese, Back to Earth History : Summary Chart for the Precambrian (http://www.scotese.com/precamb_chart.htm), Paleomar Project
29. ^ Peter Ward:[2] (http://www.nap.edu/catalog.php?record_id=11630) Out of Thin Air]: Dinosaurs, Birds, and Earth's Ancient Atmosphere
30. ^ "Summary for Policymakers" (http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf) (PDF). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change. 5 February 2007.
31. ^ Starting from [3] (http://www.merriam-webster.com/dictionary/pollution) Pollution — Definition from the Merriam-Webster Online Dictionary

External links

- NASA atmosphere models (http://modelweb.gsfc.nasa.gov/spdf_models_home.html#atmo)
- NASA's Earth Fact Sheet (http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html)
- American Geophysical Union: Atmospheric Sciences (http://atmospheres.agu.org/)
- Outreach of the GEOmon project (http://www.geomon.eu/outreach/) See how Earth atmosphere is observed and monitored by a European project that combines many approaches.
- Stuff in the Air (http://www.stuffintheair.com/) Find out what the atmosphere contains.
- Layers of the Atmosphere (http://www.srh.noaa.gov/srh/jetstream/atmos/layers.htm)
- Answers to several questions of curious kids related to Air and Atmosphere (http://www.scribd.com/doc/22854/Air-Atmosphere-and-Airplanes/)
- The AMS Glossary of Meteorology (http://amsglossary.allenpress.com/glossary)
- Paul Crutzen Interview (http://www.vega.org.uk/video/programme/111) Free video of Paul Crutzen Nobel Laureate for his work on decomposition of ozone talking to Harry Kroto Nobel Laureate by the Vega Science Trust.

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