Exploring the Earth's atmosphere

by Bob Riddle

Last month's "Scope on the Skies" was about a project involving flying weather balloons and equipment as high as possible into the atmosphere. Both flights described in that column reached altitudes in excess of 26 km (16 mi.), putting both balloons in the stratosphere at the time of balloon burst at maximum altitude. While the primary objectives of those flights were collecting video and images, the project also resulted in a good amount of science data representing the flights and conditions of the parts of the atmosphere the balloons traveled through during their ascent and descent. With the data collected and inquiring minds, much was learned about our planet's atmosphere and in turn about atmospheres around the other terrestrial planets. (See Resources for additional information and lessons about the atmosphere.)

The Earth's atmosphere is made up of several distinct layers, with each layer separated by a "pause," a transition area where there is a change between the two layers. When describing our atmosphere, the terms *opaque* and *transparent* are often used in conjunction with incoming solar radiation. Our atmosphere, in a big way, serves as a shield for much of the radiation coming from the Sun, as shown in Figure 1. Some forms of radiation are absorbed or blocked before entering the atmosphere, other forms of radiation may partially penetrate the atmosphere, while visible light and some infrared radiation are able to reach the Earth's surface.

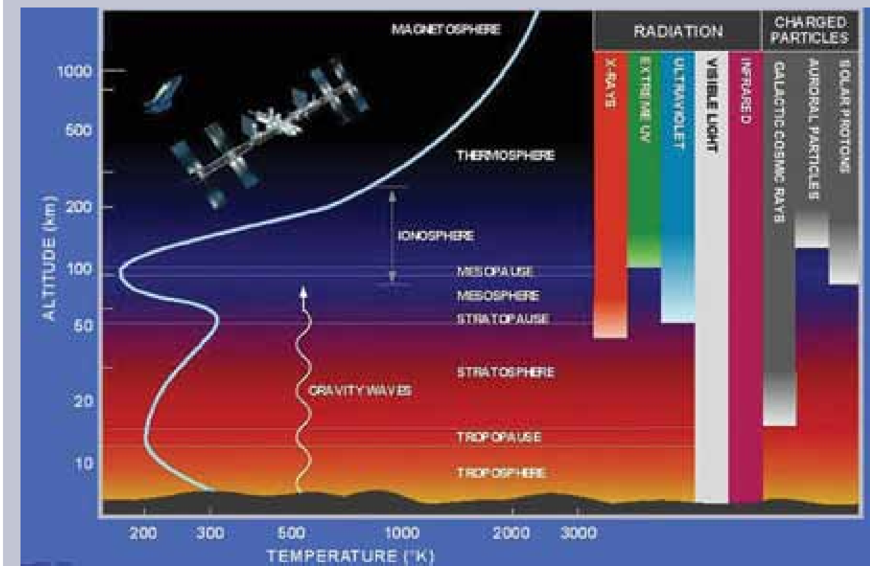
The lower atmosphere consists of the troposphere and tropopause and is the part of the atmosphere where most weather occurs. Depending on latitude,

NASA

A view of Earth's horizon as the Sun sets over the Pacific Ocean. The photo was taken by an *Expedition 7* crew member on board the International Space Station.

the troposphere extends to an altitude of around 20 km (12 mi.), with the highest altitude at the equator, and around 3 to 4 km (5 mi.) at midlatitudes. Temperature typically decreases with altitude through the troposphere, while air pressure and atmospheric density also decrease. Because there is cooler air above the warmer air near the surface, air is able to rise in convection currents, which in turn play an important role in causing our weather. The warmer surface air is a result of the Earth's surface absorbing visible light and some infrared radiation from the Sun. This is reradiated as infrared radiation, where greenhouse gases such as carbon dioxide absorb the infrared radiation, subsequently warming the air and setting up convection currents.

FIGURE 1 Layers of the Earth's atmosphere and incoming solar radiation



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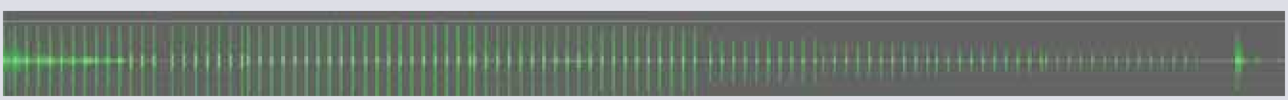
Above the troposphere is the second atmosphere layer, the stratosphere, and this is where our two balloon flights reached their maximum altitude of 28.657 km (17.8 mi.) and 26.615 km (16.5 mi.), respectively. The stratosphere extends to around 50 km (30 mi.), and within this layer, as altitude increases, air pressure and atmospheric density continue to decrease. However, temperatures actually increase with altitude. The increase in temperature is related to the abundance of the ozone molecule within the ozone layer rather than the diminishing effects from altitude of infrared radiation from the surface. The ozone layer is essentially defined by the presence of the ozone molecule and the ability of this molecule to absorb ultraviolet radiation and radiate the absorbed energy effectively enough to warm the surrounding air.

Continuing upward, the amount of ozone decreases, and passing through the stratopause there is a transition between the rising temperatures of the stratosphere and the mesosphere, where temperatures decrease. The mesosphere extends upward to an altitude of about 100 km (60 mi.), and at this altitude and upward, the density of the atmosphere and air pressure are very low. As distance increases from the warmer ozone layer, temperatures once again decrease with an increase in altitude.

The uppermost region of our atmosphere, the thermosphere, extends to somewhere around 650 to 700 km (400 mi.) above the Earth's surface. This layer, while extremely tenuous, is known for the ionosphere—the lower regions of the thermosphere where charged particles from the Sun interact with gas molecules, causing them to release photons of different wavelengths and create the spectacular and

FIGURE 2 Change in shutter sound as altitude increases from left to right



colorful aurora. The thermosphere is also known for high temperatures, hence its name. The high temperatures of the thermosphere are a result of the relatively few gas molecules absorbing high-energy ultraviolet and x-ray radiations from the Sun. Despite temperatures above 5,432°C (3,000°F), there are so few molecules that one would not really feel the "heat"—this part of space, as with all of space, is very cold. Remember: Temperature is a measure of the kinetic energy of a molecule, rather than how hot or cold something feels.

As altitude continues to increase, there will eventually be a distance from the surface where gaseous atoms and molecules are able to reach their respective escape velocity and leave the atmosphere. This region of escaping atoms and molecules is known as the exosphere. While there is not a well-defined transition from the *exosphere* to space, the exosphere is thought to extend outward to perhaps several thousands of miles from the surface.

Terrestrial planet atmosphere comparison

An *atmosphere* is defined as the gases surrounding a planet or moon. Technically, the Earth's moon, Mercury, and a few other in our solar system could be described as having an atmosphere because there are measurable atoms and molecules above the surface of these objects; however, planets and moons may best be described as having only an exosphere. Venus and Mars are the other terrestrial planets having an atmosphere, and in a general way the atmospheres of Earth, Venus, and Mars have some similarities. Despite different composition ratios, all three atmospheres have what could be considered a troposphere, thermosphere, and exosphere, with the same temperature trends of decreasing temperature as altitude increases. One big difference is that in Earth's atmosphere there is an ozone layer, or the stratosphere, where temperatures rise. On Mars and Venus, however, there is no ozone layer, so the temperature decreases steadily as altitude increases without the "bump" in temperature created by an ozone layer.

In space, nobody will hear you

Among the data collected during our two balloon flights were sounds recorded by the high-definition video camera. There were wind sounds, especially noticeable during the ascent, but what struck me as interesting was the way in which the sound of the DSLR camera shutter changed. As altitude was gained, the sound of the shutter click became more and more muted. This led to a discussion among some students and teachers about sound, how it travels, and how the altitude may have had an effect on it. Figure 2 shows the sound pattern of portions of the audio. The audio samples were taken from the video at eight-minute intervals up to and including the balloon burst. The two-minute audio file can be downloaded using the link in the Resources.

The speed of sound increases as temperature decreases, so as the balloons ascended, the sound from the camera shutter was traveling faster than it was at the surface at balloon release. However, the change in sound was a result of the lesser amount of air, specifically molecules, through which sound waves need to travel. Using two online programs, AtmosModeler Simulator and Atmospheric Properties Calculator, students can examine the effects of altitude and temperature on the speed of sound, density, and air pressure (see Resources).

Explore the atmosphere

Studying our atmosphere as well as atmospheres on other worlds is important to increase the understanding of the relationship between the atmosphere and activities on Earth (manmade or otherwise). Students can learn more about our atmosphere, atmospheric science, and careers in this field by taking advantage of the many resources available. The National Oceanic and Atmospheric Administration and NASA are both deeply involved with observing and studying the atmosphere. A casual glance at the current mission listing at the NASA website shows no fewer than 20 missions focused on observing the Earth's atmosphere. Students could learn about the role of an atmospheric scientist or about other sciences at the Astro-Venture website maintained by NASA Ames Research Center. How High Is It? is one of the activities in a NASA-developed educator packet about scale distances by the same name. In this paper-based activity, students work with a scale model of the layers of the Earth's atmosphere to place various flying and orbiting objects at their respective distances from the Earth's surface (see Resources). ■

Visible planets

Mercury will remain visible through most of the month as a morning planet over the southeastern horizon.

Venus will shine brightly above and to the right of Mercury and will remain visible as the brightest of the three morning planets this month.

Mars will be visible over the southwestern horizon at sunset.

Jupiter will be easily seen near the reddish star Aldebaran in Taurus the Bull over the eastern horizon at sunset.

Saturn will be the third morning planet; from Venus, look up to the right over the southern horizon for the ringed planet.

December

3	Jupiter at opposition
4	Mercury at western elongation
9	Vesta at opposition
	Mercury near Venus
	Waning crescent Moon near Spica
	Cassini flyby of Titan
12	Jupiter near Aldebaran
	Moon at perigee: 357,100 km (221,892 mi.)
13	Geminid shower peak
	Uranus stationary
15	*Cassini* flyby of Titan
18	Sun enters astronomical sign of Sagittarius
	Mercury near Antares
	Ceres at opposition
21	December solstice 6:12 a.m. EST
	Sun enters astrological sign of Capricornus
22	*Cassini* flyby of Titan and Rhea
23	Venus near Antares
25	Moon at apogee: 406,100 km (252,339 mi.)
26	Uranus at east quadrature
30	Pluto in conjunction with Sun

Resources

Ascent balloon flight audio—*http://sdrv.ms/N37acW*

Astro-Venture—*http://astroventure.arc.nasa.gov*

AtmosModeler simulator—*www.grc.nasa.gov/WWW/k-12/airplane/atmosi.html*

Atmospheric properties calculator—*www.aerospaceweb.org/design/scripts/atmosphere*

Atmospheric science career—*www.careercornerstone.org/pdf/atmsci/atmsci.pdf*

Cassini Saturn mission—*http://saturn.jpl.nasa.gov*

Current NASA missions—*www.nasa.gov/missions/current*

Earth's atmosphere—*http://redorbit.com/education/reference_library/earth/atmosphere/2574996/earths_atmosphere*

Geminids meteor shower—*http://meteorshowersonline.com/geminids.html*

How High Is It?—*http://virtualastronaut.tietronix.com/teacherportal/pdfs/How.High.Is.It.Educator.Guide.pdf*

Layers of the atmosphere—*www.srh.noaa.gov/jetstream/atmos/layers.htm*

Liftoff to Learning: The Atmosphere Below video—*http://archive.org/details/liftoff_to_learning_5_the_atmosphere_below*

National Oceanic and Atmospheric Administration—*www.noaa.gov*

Questions for students

1. Using Figure 1, explain why telescopes for studying x-rays are placed in Earth's orbit, rather than on the Earth's surface. (*X-rays barely penetrate the Earth's atmosphere, so a telescope in Earth's orbit places it where x-rays are observable.*)
2. Many planets have an atmosphere; however, the atmosphere around Earth, while supporting life, is unique in other ways. One big difference, with regard to temperature and air pressure, and considered significant for life on Earth is…? (*Our atmosphere is the only one with air pressure and temperature within the right ranges for water to exist in all three states of matter [gas, liquid, solid] at the same time.*)
3. The atmosphere of Mars lacks a stratosphere, which would suggest a lack of what in its atmosphere? (*The stratosphere is an atmospheric layer where there is a temperature increase as a result of the interaction between ultraviolet radiation from the Sun and ozone molecules. Because temperatures steadily decrease with altitude in the Martian atmosphere, and there is not a layer of the atmosphere where temperatures increase, there must be little or no ozone in the Martian atmosphere.*)

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