MAGIC

2015-02-12 update

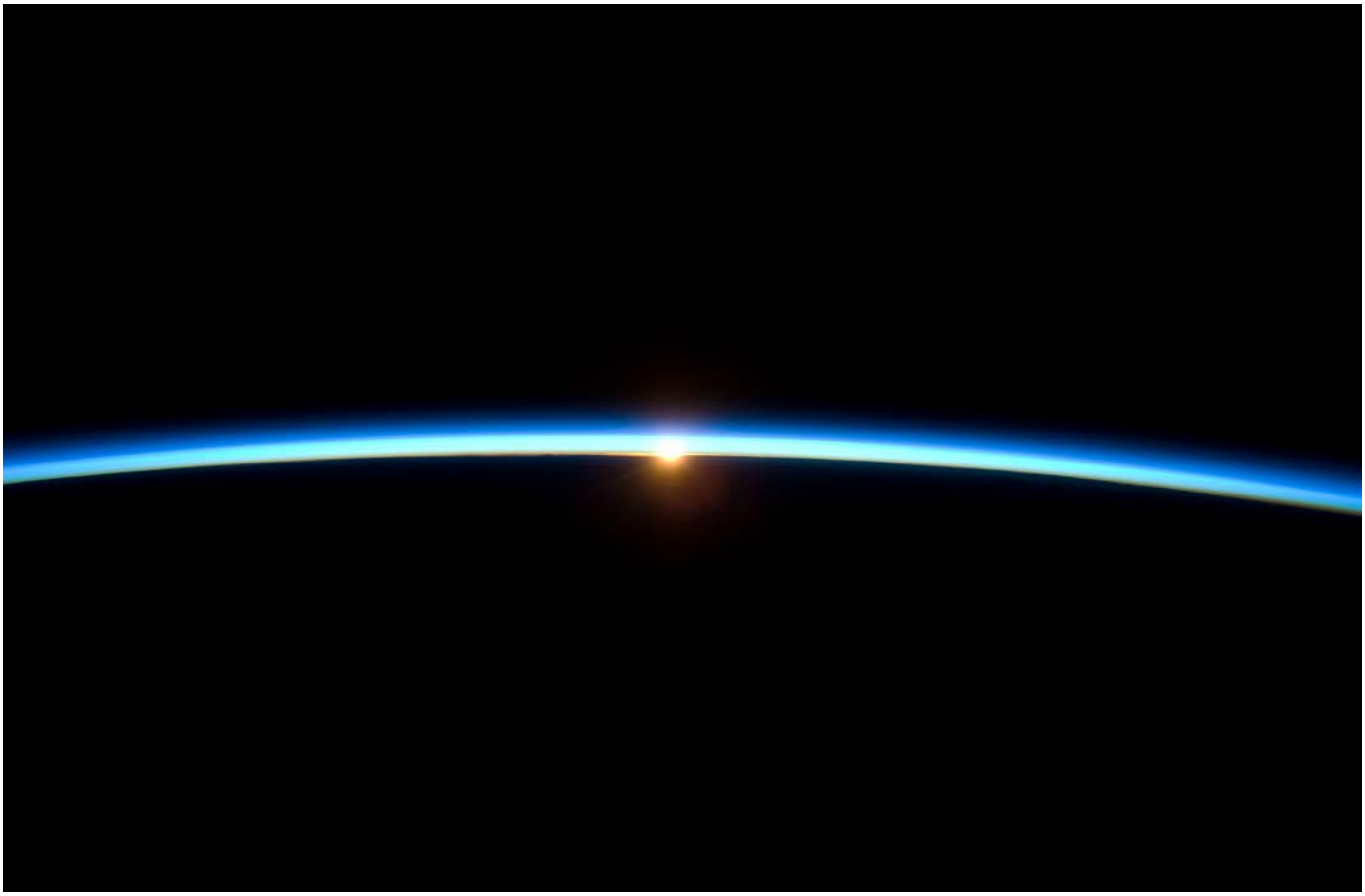
A newsletter for non-scientists (and scientists) interested in MAGIC and science

MAGIC was a field program funded and operated by the Atmospheric Radiation Measurement (ARM) Climate Research Facility of the U.S. Department of Energy. The ARM MAGIC webpage is http://www.arm.gov/sites/amf/mag. Information on MAGIC and all previous updates can be found at http://www.bnl.gov/envsci/ARM/MAGIC/.

The atmosphere is of considerable importance to us, as it contains the air that we breathe. The word "atmosphere," which means the gases surrounding a planet, derives from two Greek words, *atmos* (vapor, or steam) and *pharia* (sphere), and was first used in 1638 in reference to the atmosphere of the moon (which for all practical purposes doesn't have one). Scientists are interested in many aspects and properties of the atmosphere. In this update I will discuss its composition–what it is made of.

The air that fills our atmosphere is comprised almost exclusively of nitrogen and oxygen, with small amounts of other substances. More precisely, approximately 78% of the number of molecules and atoms that comprise *dry* air are nitrogen molecules, 21% are oxygen molecules, and 1% are argon atoms, and these fractions are very nearly constant throughout the atmosphere, anywhere on Earth and independent of time of day or season. “Dry air” refers to air without any water vapor (i.e., water molecules in gaseous form, as opposed to liquid or solid [ice] form). Water vapor is often the third most abundant constituent of the atmosphere, but the fraction of water vapor molecules in air (which is determined by the relative humidity and the temperature) varies greatly, both with time and with location. As I write this, in the middle of winter, approximately 0.3% of the number of air particles (i.e., molecules and atoms) outside my window are water vapor molecules, but in summer at this same location, this fraction may be as high as 6%. Because the amounts of other major constituents of air are relatively constant, whereas that of water vapor is not, the concept of *dry* air simplifies discussion.

How much air is there? One way of looking at this question is to consider the effective height of the atmosphere; that is, the thickness it would be if the air didn’t get less dense with increasing elevation but rather remained the same density everywhere. This value is about 8.5 km (5 miles), roughly twice the average depth of the oceans. This effective height of the atmosphere compared to the size of Earth is equivalent to a thickness of just over one coat of paint on a baseball–incredibly thin!



This picture, taken from the International Space Station on November 23, 2009, illustrates how thin the atmosphere really is.

Air also contains smaller fractions of other, “trace” substances, the most abundant of these being carbon dioxide (0.04%), followed by neon (0.002%), helium (0.0005%), and methane (0.0002%). There are many others with even lower fractions. Some of these trace components are produced by humans, and thus their abundances vary considerably with location (e.g., greater in cities) and time (e.g., greater at rush hour), making it difficult to give meaningful values for their amounts. An easy way to visualize the abundance of one of these trace constituents is by considering the height of the layer it would form if all of that substance were at the surface. All of the carbon dioxide in the atmosphere, for instance, would form a layer approximately 3.4 m (just over 11 feet) thick. The corresponding thickness for neon is 14 cm (5.5 inches), that for helium 4 cm (1.5 inches), and that for methane 1.5 cm (0.6 inches).

Although the abundances of some of these substances may be very small, their impact may nevertheless be very large. A prime example is ozone, most of which is located miles above the surface in the ozone layer, which is in the stratosphere (more about this in a later update). Ozone molecules comprise only around 0.00003% of the number of particles in the atmosphere (and would form a layer at the surface 2.5 mm, or 1/10 inch, thick), but they absorb much of the ultraviolet light from the sun before it reaches Earth's surface (and us). This ultraviolet light has sufficiently high energy that it can cause severe sunburn and break chemical bonds in our skin such as those in DNA molecules, which can lead to skin cancer. Without ozone in the atmosphere, the amount of this high-energy ultraviolet light at Earth's surface would be several hundred million times greater than it currently is; thus the concern about fluorocarbons, which destroy the ozone layer. The total amount of Freon-11, Freon-12, and Freon-113 (the major fluorocarbon substances of interest) in the atmosphere is slightly less than one part per billion (less than 0.0000001%), which is equivalent to a layer at the surface only one quarter of one thousandth of an inch thick (one tenth the diameter of a human hair), yet their adverse effects on ozone in the stratosphere is so strong that they were banned by the 1989 Montreal Protocol. Thus, just because something isn't abundant doesn't mean it isn't important.

In future updates I will discuss the structure of the atmosphere.

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